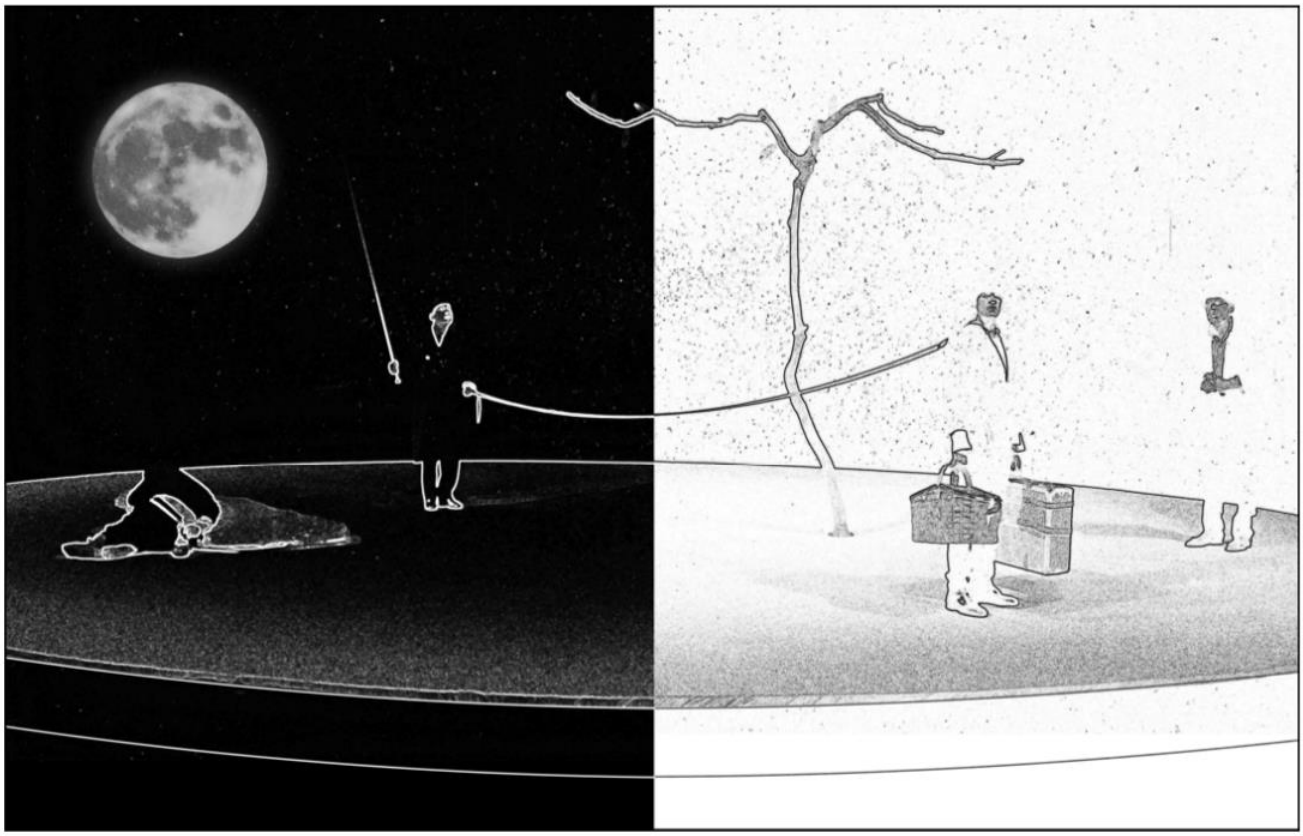
PHD THESIS

A Seeing Place

Connecting Physical and Virtual Spaces



JOSEF WIDESTRÖM

DEPARTMENT OF COMPUTER SCIENCE
CHALMERS UNIVERSITY OF TECHNOLOGY
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THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

A Seeing Place
Connecting Physical and Virtual Spaces

JOSEF WIDESTRÖM

Department of Computer Science and Engineering

CHALMERS UNIVERSITY OF TECHNOLOGY

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JOSEF WIDESTRÖM

Division of Interaction Design
Department of Computer Science and Engineering
Chalmers University of Technology

Abstract

In the experience and design of spaces today, we meet both reality and virtuality. But how is the relation between real and virtual construed? How can we as researchers and designers contribute to resolving the physical-virtual divide regarding spaces? This thesis explores the relations between the physical and the virtual and investigates ways of connecting physical and virtual space, both in theory and practice.

The basic concepts of the thesis are *Space*, *Place*, and *Stage*. The central idea is that the stage is a strong conceptual metaphor that has the capacity to work as a unifying concept relating physical and virtual spaces and forming a place for attention, agreements, and experience – *A Seeing Place*. The concept of seeing place comes from the Greek word *theatre*, meaning a "place for seeing", both in the sense of looking at and understanding.

In certain situations, the relations between physical and virtual spaces become important for users' experience and understanding of these situations. This thesis presents seven cases of physical-virtual spaces, in the field of architectural and exhibition design. The method of these studies is research by design. The discussion then focuses on how each setting works as a stage, and how conceptual metaphors can contribute to the connection between physical and virtual spaces.

Building upon the explorations and experiments in different domains, the thesis contains a collection of seven papers concerning the relations between physical and virtual space in different contexts outside the world of theatre. These papers range from more technical about Virtual Reality (design of networked collaborative spaces) to more conceptual about staging (methods in interaction design) and virtual space (using a transdisciplinary approach).

The results of those studies suggest that the *Stage* metaphor of a physical-virtual space can contribute to the elucidating of relations between physical and virtual spaces in number of ways. Conceptually, the stage metaphor links together the semiotic and the hermeneutic views of space and place. And, from a practice-based perspective, *A Seeing Place* view opens up the way to creating contemporary spaces and resolving the physical-virtual divide.

Acknowledgements

First of all, I thank my supervisor Prof Gordana Dodig-Crnkovic and co-supervisor Prof Karin Wagner for their sustained encouragement and constructive criticism. I also thank my previous supervisor Prof Sven Andersson for his positive support and for initiating the Digital Representation research school. The other members of the research school, particularly Dr Thommy Eriksson, have given me invaluable input and critique in our seminars and informal discussions.

My research and teaching environment at the Division of Interaction Design has provided an excellent ground for transdisciplinary research, with colleagues of high expertise and not least managers (Docent Jonas Landgren, Prof Staffan Björk, and Prof Palle Dahlstedt) that have shown patience and interest in my work giving me time to complete the thesis. Thank you Agneta Nilsson, Deputy Head of Department, for giving me structure and deadlines.

This research could not have been done without external organisations providing cases for my studies. A special credit to my colleague at Arctic Studio, Björn Gross, who shares my interest in developing new architectural concepts. Staff and managers at the museums and science centers I have studied have been helpful and supportive, especially at Universeum.

Finally, I thank my lovely family who have forgiven me for working on this thesis over weekends and vacations. We can go and see that movie now.

Preface

When I came to Chalmers Medialab in August 1998, the hype of Virtual Reality was at its peak. Chalmers had just invested in a giant Silicon Graphics super graphics computer, connected to a state-of-the art VR CUBE display system. This was where all the new amazing scientific visualizations were going to be happening. I remember stepping into the server room the first time, awed by the long row of refrigerator-sized computers.

For eight years, I had the privilege to work in high-end Virtual Reality projects with specialists from a wide range of scientific and artistic domains; architecture, city planning, mechanics, biophysics, acoustics, choreography, theatre, and many more. In the mid 2000s, Virtual Reality had lost some of its magic. This technology was said to be too complicated, too expensive, not enough entertaining, and not making enough use in "real life". In my own research, I started to dig deeper into the theories behind the central concepts of my projects; virtuality, reality, embodiment, visualization, representation, interaction.

Then, in the early 2010s, things were starting to happen again. Suddenly, off-the-shelf Virtual Reality displays that had been anticipated for twenty years appeared on the market. Visualization centres and arenas emerged, where industry and academia could collaborate, test, discuss and develop new projects. Myself being part of the first hype some fifteen years earlier, I looked at this renaissance of Virtual Reality with some scepticism. It was like hearing an echo from the past when people started talking about the same old ideas as innovative, like it had never been thought of before.

My own research interest became more focused on using virtual spaces as interface between people and less on the technology itself. It became clear that a common theme for my work is the relations between physical and virtual spaces. This is when I realised that a thesis based on my research all the way back from the late 1990s into the early 2020s could give me a solid base for future research and contribute to the domain of Virtual Reality.

Whatever that is.

Onsala, Sweden, February 2020

List of Publications

This thesis is based on the research published in the following seven papers (I-VII):

I. Josef Wideström, Ann-Sofie Axelsson, Ralph Schroeder, Alexander Nilsson, Ilona Heldal, and Åsa Abelin (2000) The collaborative cube puzzle: a comparison of virtual and real environments. In Proceedings of the third international conference on Collaborative virtual environments (CVE '00), Elizabeth Churchill and Martin Reddy (Eds.). ACM, New York, NY, USA, 165-171.

II. Josef Wideström and Pia Muchin (2000) The Pelvis as Physical Centre in Virtual Environments. In: PRESENCE 2000, the 3rd Annual International Workshop on Presence, March 27-28, 2000. Delft, The Netherlands

III. Ilona Heldal, Ralph Schroeder, Anthony Steed, Ann-Sofie Axelsson, Maria Spante, Josef Wideström. (2005) Immersiveness and Symmetry in Copresent Scenarios. Published in Proceedings of the IEEE Virtual Reality 2005 (VR'05) 1087-8270/05. Bonn, Germany, March 2005.

IV. Erikson, E., & Widestrom, J. (2014) Staging the interaction – Explorative interventions for engaging citizens in the development of public knowledge institutions. In Proceedings of DRS2 014: Design's Big Debates (pp. 1096- 1108), Umeå, June 2014. London: Design Research Society.

V. Eva Eriksson and Josef Wideström (2015) The Virtual Culture House – Shaping the Identity of a Public Knowledge Institution. Proceedings of 11th European Academy of Design Conference. April 22-24. Paris, 2015.

VI. Wideström, J. (2019) The Transdisciplinary Nature of Virtual Space. Lecture Notes in Computer Science. ISBN 978-3-030-25964-8. Vol. 11613 LNCS p. 186-202. Publication from the conference: Salento AVR 2019, 6th International Conference on AR, VR and CG. 2019. Springer Nature Switzerland.

VII. Wideström, J. (2020) Designing for Science Center Exhibitions, A Classification Framework for the Interaction. Accepted at DESIGN Conference, Oct 26-29, 2020. To be published in: Proceedings of the Design Society: DESIGN Conference. Cambridge University Press. ISSN 2633-7762. https://www.designconference.org/

Summary of papers

I. The Collaborative Cube Puzzle: A Comparison of Virtual and Real Environments

In this study we compared collaboration on a puzzle-solving task carried out by two persons in a virtual and a real (physical) environment. The task, putting together a cube consisting of different coloured blocks in a Rubiks' cube type puzzle, was performed both in a shared virtual environment (VE) setting, using an immersive Cave-type virtual reality (VR) system networked with a desktop VR system, and with cardboard coloured blocks in an equivalent real setting. The aims of the study were to investigate collaboration, leadership and performance in the two settings. We found that the participants contributed unequally to the task in the VE, and also differences in collaboration between the virtual and the real setting. My contribution to this paper was to come up with the overall concept of the puzzle and design the settings in the virtual and physical (here called 'real') spaces. I prototyped both designs and tested so that they could be solved in the desired time span, but not too easily. I also built the puzzles and programmed the VR systems to make the interaction work in this shared VE. This setup was then reused for further research and published in other papers and articles.

II. The Pelvis as Physical Centre in Virtual Environments

The increasing uses of virtual environments (VE's) stress the importance on how the human body relates to the concepts of motion and space. Normally, the visual sense is used as the centre of VE's, with the eyes as physical control point. However, our study shows that the pelvis should be used as physical center to create the necessary connection between humans and virtual space in order to minimise distress. My role in this project was to contribute with theoretical and practical expertise in architecture (physical space) and Immersive Projection Technology for VR (virtual space).

III. Immersiveness and Symmetry in Copresent Scenarios

Collaboration at a distance has long been a research goal of distributed virtual environments. A number of recent technologies, including immersive projection technology systems (IPTs) and head-mounted displays (HMDs), promise a new generation of technologies that are more intuitive to use than desktop-based systems. This paper presents an experiment that compares collaboration in five different settings. Pairs collaborated on the same puzzle-solving task using one of: an IPT connected to another IPT, an IPT connected to an HMD, an IPT connected to a desktop system, two connected desktop systems, or face-to-face collaboration with real objects. The findings demonstrate the benefits of using immersive technologies, and show the advantages of using symmetrical settings for better performance. Some usability problems of the different distributed settings are addressed, as well as factors such as "presence" and "copresence" and how these contribute to the participants' overall experiences. My contribution to this paper was to manage the design of all the five settings, and ensure symmetry and consistence regarding interfaces to the collaborative task.

IV. Staging the Interaction – Explorative Interventions for Engaging Citizens in the Development of Public Knowledge Institutions

In this paper, six different classes of methods of exploratory interventions for engaging citizens in the development process of public knowledge institutions is presented. The classification is based on twelve implemented and tested exploratory installations, and can be used as inspiration for stakeholders in order to work systematically with the stakeholder-citizens' interaction. The discussion is centred on intertwining the physical and the virtual, and exemplified through the development process of a new culture house. The contribution of this paper is the classification of methods that a) address the connection of physical and virtual spaces and b) stage the interaction between different actors relevant for the development of the design process, through interactive tools that can be a complement to using the traditional virtual 3D-models, physical architectural models, or public hearings. My contribution to this paper was to set a task for the design teams, after assessing the design context and the variety of needs of the stakeholders. My role was also to assess the explorative interventions regarding different aspects of the project and design the framework for the paper.

V. The Virtual Culture House – Shaping the Identity of a Public Knowledge Institution

In this paper, we discuss how a virtual platform can be used in order to explore communication forms for stakeholders in the planning process of public knowledge institutions. The paper presents the Virtual Culture House, an attempt to stimulate the communication among stakeholders and users of a future culture house. The project is cooperation between Chalmers University of Technology and the municipality of Lundby in Sweden and aims to find new ways of complementing the traditional architectural visualizations and public hearings for engaging citizens in the development process of public knowledge institutions. The contribution of this paper is two-fold; firstly it presents a virtual platform based on activities to complement the traditional methods for involving stakeholders in the development process of public knowledge institutions, and secondly, it introduces visitors, citizens, contributors and officials as stakeholders on equal ground, and claim that such a dialogical tool can support user involvement and participation and stimulate both staged activities and self-motivated activities. The Virtual Culture House forms, together with the physical local community, an activity-based physical-virtual space that shapes the identity of the future physical culture house. In this project, me and Eriksson shared the management and the communication with the stakeholders. My contribution was to set the context and formulate the design problem of the Virtual Culture House, based on the classification model presented in the previous paper "Staging the Interaction".

VI. The Transdisciplinary Nature of Virtual Space

This paper presents a transdisciplinary view on virtual space, through a description of how different domains of knowledge inform the concepts of virtuality and space. The aim is to show how these different perspectives come together in the virtual space that facilitates combining science and technology with cultural aspects coming from arts and other domains of knowledge. The argument leads to two models of the understanding of virtual space. The first model is an explanation of virtual space as a hybrid that has emerged from both nature (represented by sciences) and culture (represented by arts). The second model puts the observer in the center, exploring the physical-virtual space through an embodied interaction. The contribution of this paper is twofold. First, it presents virtual space as a platform for transdisciplinary work, exposing its underlying processes from both theoretical and practical point of view. Second, it introduces a model for the way transdisciplinarity can inform the understanding of virtuality that is taking increasing part of our everyday lives as well as variety of knowledge production in form of advanced visualizations, simulations and virtual reality approaches. I am the sole author of this paper.

VII. Designing for Science Centers - A Classification Framework for the Interaction

While designing and discussing exhibitions in science centers, common conceptual framework is needed. This paper provides a framework based on participation, virtuality, and collaboration, and two models - a Rubik's cube model and a Scatter plot space. They are suitable tools for analysis and overview of existing and planned exhibitions, as well as for conceptual analysis during the design process. The classification and the models for the interaction have been developed in a research by design process, where 45 prototypes have been designed, exhibited and tested. The contribution of this paper is to provide designers and planners of science centers with a framework that can support design work and evaluation. I am the single author also of this paper.

List of Acronyms

AI	Artificial Intelligence
AR	Augmented Reality
CAD	Computer-Aided Design
CVE	Collaborative Virtual Environment
HMD	Head-Mounted Display
ICT	Information and Communication Technology
IPT	Immersive Projection Technology
IT	Information Technology
MR	Mixed Reality
POV	Point of View
RQ	Research Question
VE	Virtual Environment
VR	Virtual Reality

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Background of the Author

This PhD thesis is a result of some twenty years of research in Digital Representation, Virtual Environments, Visualization, and Interaction Design at Chalmers University of Technology in Göteborg, Sweden. Digital Representation is a cross-disciplinary research area that involves artistic research as well as humanistic research and science. In Gothenburg this research area has been performed collaboratively between the Department of Applied IT at Chalmers and the School of Film and Photography at Gothenburg University. Theoretically, Digital Representation is based on semiotics (the theory of signs and sign relations), hermeneutics (the theory of interpretation), and art and media theory applied in the digital realm. This multi-disciplinarity means that the research questions and problematizations can occur in a wide spectrum of subjects, implying that the agreements and the mutual understanding of the writer and the reader are especially important to establish. Research work in this domain can be understood through the lenses of art, architecture, photography, design, cognition, virtual reality, visualization, semantics, information technology, literature, or other. Other PhD work in Digital Representation (Crawford, 2009; T. Eriksson, 2017; Ljungar-Chapelon, 2008; McCallum, 2018; Munoz, 2013; Vikhagen, 2017) at Chalmers and Gothenburg University has emphasized this diversity of the domain. In Digital Representation the artistic aspect is vital to the work and a common ground in all research within this area. This artistic ambition means that the research work exists in close relation to the researcher, in the same way that any work of art exists in relation to its creator. In that sense, artistic research becomes personal and inseparable from the questions of where, when, and by whom, the work has been done.

I work at Chalmers Department of Computer Science, Division of Interaction Design, as a lecturer, researcher, and PhD student. I am an architect by education, with a Master of Science in Architecture from 1998. Since then I have been working as a teacher in Digital Representation, Virtual Environments, Visualization, and Interaction Design, and also as a project manager for Virtual Reality projects at Chalmers. I was managing the Chalmers VR Cube, first at Chalmers Medialab (1998-2002) and then at CKK[1] (2002-2006). From 1999-2001 I was also part of the Technology and Society research group at Chalmers that focused on social implications of Virtual Reality. I have been involved in more than twenty VR projects, with applications ranging from architecture and urban planning to biophysics and acoustics. Some projects have been more artistic and others more scientific. However, my focus has always been on the virtual space; how it is experienced and what it means to be a human actor in this space. Since 1993 I have been working with set design (stage design or scenography) for theatre plays and dance performances in both small- and large-scale productions. In 2001 I started up a studio[2] that works cross-disciplinary with art, architecture and design. My experience from all these activities as well as an artistic background in a wide range of professional domains constitutes the base for the ideas that I present in this dissertation (Fig. 1-3).

Progression

The progression of my research is represented in the topics of the papers included in this thesis and also other papers I have published over the years. My early work regarded mainly VR technology and use of technology, which lead to an interest in interaction, embodiment, presence and co-presence. Then, my interest shifted more towards societal and social aspects of VR, broadening the research topics into studying these technologies as an interface between people, and not only between human and computer. Lately, my main focus has been on philosophical, artistic, and ethical questions regarding virtual spaces. Here, I have connected back to my practice of designing physical spaces as an architect and a set designer.

[1] Centre for Learning in Higher Education at Chalmers, see http://www.ait.gu.se/ckk

[2] Arctic Studio, see http://www.arcticstudio.se

Examples of previous work

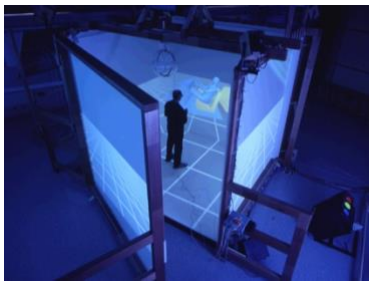


Figure 1. Simulation of Thermo-fluid dynamics, Chalmers VR Cube, Gothenburg 2001

Figure 2. Architecture of *Villa Cliffhanger,* Arctic Studio, Lerum, 2008

Figure 3. Stage design of *Lisa Louise*, Helsingborg City Hall Theatre, 2003

Process

This PhD work started in 2007, focusing on the semiotics of physical and virtual spaces in architecture. In 2009 I had my 25% seminar, presenting two examples, the first being a comparison of physical and virtual spaces for art (museums and art galleries), while the second example was an analysis of parallel work processes in developing both physical and virtual architecture. The ambition of that work was to explore the notion of *the unification of physical and virtual space*. This concept constitutes the foundation of my work and is elaborated further in the current text. For my 50% seminar in 2012, the focus was on the *interpretation and representation of physical-virtual space*. That is, spaces which are both physical and virtual, such as museums and science centers. Since my 75% seminar in 2016, the focus has been on *physical-virtual space as a stage for experience and agreements*.

Disposition

This thesis has been written during a long period of time, connecting to a progression in research focus and interest and experiences made in design of architectural spaces, Virtual Reality projects, and interactive exhibitions. It is a hybrid of the two established formats; a compilation of papers and a monograph. It means that the contributions in relation to the research questions are also made in the introductory chapters and that these chapters therefore are more than a summary of the papers.

Since this thesis aims at contributing to both theory and practice, there is a balance of theoretical and practical approaches. In Chapter 1, the research questions are presented and related to the published papers and explored cases. Chapters 2-4 are mainly theoretical, while Chapter 5 with all the cases has a more practical focus. Chapter 6 contains a summary of contributions, discussion, and conclusions. The disposition follows the order of introduction, method, theory, result, and final conclusions, putting the cases in the later part of the text.

The central concepts *space, place*, and *stage* will be explored in this thesis. There is a logic and systematics in the way concepts are introduced, with new concepts building on the previous ones. The fundamental notion of space is introduced in the sense of physical, virtual and semiotic space, followed by place that denotes space in relation to human connection, and works as a link to the concept of stage metaphor based on the theatre stage. Case is in this text is a particular implementation of the concept of stage presented through two underlying ideas of space and place. The structure of the text in relation to these central concepts is therefore:

Space → Place → Stage → Case

1. Introduction

Nowadays, in our homes and workplaces, we are not always present only in a physical environment. We also experience virtual environments,[3] mediated through different devices. This co-existence of physical and virtual space creates a challenge for designers, architects, and artists that work with spaces for human interaction and experience. This thesis explores the relation between physical and virtual spaces. When we design and experience spaces today, we relate to both reality and virtuality. But how is that done, what are the problems and how can these relations be designed and constructed to support and enhance each other? And, how can we as researchers and designers contribute to resolving the physical-virtual divide regarding spaces? In certain circumstances, in both professional and everyday situations, the relations between physical and virtual spaces are important to understand for designers. The motivation is to design coherent physical-virtual spaces for human interaction.

My proposal for solving this creative challenge is to use stage design (scenography) to approach the relations between physical and virtual spaces. In stage design the co-existence of physical and virtual is contextual, well studied and has a long tradition, in the way of fluently combining imaginary/immaterial objects and spaces with realistic/authentic objects and spaces. By taking this stance, we can see the physical-virtual space in a new light and apply methods and models from stage design to address situations and solve design problems outside the world of theatre. I have studied seven different cases that represent physical-virtual space relationships and configurations. The discussion then focuses on how each of configurations works as a stage, and how the spaces are organised as a set design.

The designer and theoretical domains upon which this thesis builds are architecture, interaction design, and theatre (Fig 4). These domains are used as different looking glasses when exploring virtual spaces. Architecture, since these questions deal with humans in a world of constructed structural limitations. It involves homes, workplaces, urban spaces, and other environments for everyday human life. Interaction design, through a focus on interactivity with spaces using information technology as design material. And theatre, by the introduction of the stage metaphor and the idea of the seeing place.[4] The core of this thesis therefore lies in the intersection between architecture, interaction design, and theatre.

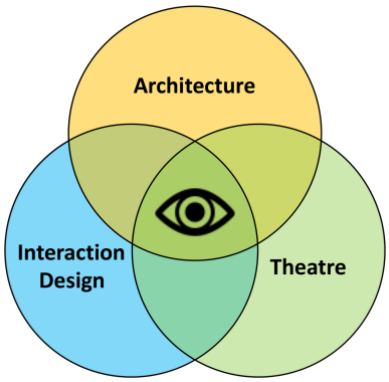


Figure 4. The domain of the thesis is in the intersection

[3] Virtual Environments, as including various types of virtual and augmented realities.

[4] "Theatre, also spelled theater, in architecture, a building or space in which a performance may be given before an audience. The word is from the Greek theatron, "a place of seeing". A theatre usually has a stage area where the performance itself takes place. Since ancient times the evolving design of theatres has been determined largely by the spectators' physical requirements for seeing and hearing the performers and by the changing nature of the activity presented."
(https://www.britannica.com/art/theater-building)

Scope of the Thesis

Artistic, technological and sociological aspects of architecture, digital media, theatre, literature, games, film and virtual environments are constantly explored in research projects. The focus of my doctoral thesis is to find common *spatial aspects* in this broad spectrum, using knowledge from these domains in order to explain how we create and perceive meaning in relation to space, as individuals and as a community. Just like we say that deep meaning in a text is read between the lines, that is in the relationships and interactions, this thesis wants to explore meaning in the relations and interactions between different spaces.[5] My research also spans over different levels of abstraction,[6] connecting concrete design problems and technological issues with philosophy and theory of virtual space. The levels of abstraction in this thesis (from lowest to highest) are: Design Practice, Philosophy of Design, Semiotics and Hermeneutics, and Metaphysics. Using multiple levels of abstraction gives structure to the transdisciplinary approach of this thesis, as the analyses are made both in detail and overview and cross over different disciplines.

When addressing the research question on the relation between virtual and physical space I will focus on the following three aspects:

1. **The relation between expectation, experience and understanding.** The experience of virtual spaces can give expectations of physical spaces, for example in how architectural visualizations can help with understanding a future or remote building. These expectations may or may not then be fulfilled in the experience of, and the interaction with, the physical space and objects. These fulfilled expectations, or different misunderstandings, affect experience of both physical and virtual space. In visualizations of worlds that we cannot perceive without assistance, such as scientific visualizations of microcosmos, no perceptual comparison can be made between the virtual representation and the physical space, which means that expectations and experiences can only emerge in the interaction within the virtual worlds. In these applications the virtual representations can even have the potential of being understood as real, since no real-life alternative exists. Secondly, that we, as humans, have conceptions of physical space in terms of gravity, friction, perspective view, motion and interaction that altogether create unavoidable expectations of virtual space. These expectations can then be fulfilled or broken in the experience of the virtual, which creates new experiences and new understanding. Nevertheless, the expectations and experiences themselves are always real for an involved observer, regardless whether they come from physical or virtual spaces.

2. **Connection and coexistence of physical and virtual space.** In our physical environments today, the coexistence of multimodal[7] virtual environments has become common, mainly in visual representation but also through sound and other sensory modes. This presence of complementary input and interaction creates a virtual space[8] where we can be present instead of, or in connection with, the physical space. Coexistence of physical and virtual spaces can have an everyday flavour as in information displays, mobile phones and television screens in housing, workplaces, vehicles and public spaces, or it can occur in special events as in theatres, arenas or exhibitions. For example, science centers make use of this coexistence and connection of physical and virtual space to enhance the experience and understanding of the

[5] Spaces, as in multiple subsets of the wider entity of abstract space.
[6] The amount of complexity and detail by which a system is viewed. Further explained in chapter 2.
[7] Interaction using multiple sensory modes, such as visual, auditory and haptic modes.
[8] A perceivable and digital non-physical space. The meaning of 'virtual space' is elaborated in chapter 3.

scientific content of the exhibits. There is an interplay between physical and virtual where the illusion meets the physical both in everyday and in special occasions.

3. **The role of virtual models for different stakeholders.** Virtual modelling is an important tool and method of communication, not only between the creator/designer and the audience/user but also for the creator/designer in the self-reflecting communication in the design process. Not least in architectural work virtual models play a major part in the materialisation of ideas. A wide range of models leads towards the creation of the built environment. The architect is testing the design both on himself, clients, builders and decision makers, which results in new versions and designs. Moreover, this virtual architecture creates expectations on the physical setting, so that the understanding of the physical building is affected by what has been experienced from the computer images and virtual models along the way. The choice of medium and the degree of realism in this virtual architecture are important factors for what will be expected from the future physical architecture. Therefore, the physical environment is not detached from its virtual representation but concretely depends upon and emerges from these virtual images and models with these images and models. This interplay between architecture and image also becomes evident when the physical environment is being photographed or replicated in virtual 3-D models and spread to a much larger audience than the number of people that experience the physical environment. There can consequently be aspects of architecture where the virtual representations are actually more important than the physical building. As a result, there are buildings today that are created primarily with the image of the architecture in mind.[9] The physical architecture becomes an anchor-point in reality for different virtual representations. Together with the design process these physical and virtual representations form the gestalt[10] of the architectural intentions. In the case of a completely virtual project without intentions of creating physical architecture, this anchor-point is missing but for the viewer it can be hard (or irrelevant) to decide whether the designed virtual space is supposed to exist in physical space.

Research Questions and Hypothesis

As I will discuss in this thesis, the integration of virtual spaces in physical spaces and vice versa is problematic, both practically and conceptually. In many situations today where virtual and physical spaces co-exist there is a lack of unifying design concept that works for both contexts. On a philosophical level, the notion of virtuality is important for the understanding of these relations, where different interpretations of virtuality have different implications (Deleuze, 1993; Ettlinger, 2007; Heim, 1994). It is problematic that, in many aspects, there is a lack of founding theories for the connection between physical and virtual space.

The focus of my research is the study of these connections between physical and virtual space. This research examines the relations between the physical and the virtual, investigating agreements, interactions and experiences in relation to spaces, through both practical explorations and theoretical study. In order to explore these relations, I use the concepts of *Space*, *Place*, and *Stage*. Space for the structural properties, place in relation to human

[9] For example, the famous *Museum of Bilbao* by Frank Gehry can in some respects be understood as an image more than a building.

[10] In the translation of *gestalt* into English *representation* the broader sense of *gestalt* is lost. German *Gestalt* (shape, figure, form) stands for a collection of elements that creates a whole, unified concept or pattern which is other than the sum of its parts, due to the relationships between the parts).

connection, and stage as unifying concept. The general idea is that strong conceptual metaphor of stage can work as unifying concept in the relations between physical and virtual spaces and form a common place for attention, agreement, and experience.

The general setup is illustrated in Figure 5, where one or several users/actors[11] interact with both physical and virtual objects and spaces. As I will elaborate further in this thesis, users make different agreements and interact differently with physical and virtual spaces and objects respectively.

The leading research questions addressed in the thesis are:

RQ1: What are the relations between physical and virtual space?

RQ2: How do metaphors support conceptualization and implementation of the relations between physical and virtual space?

RQ3: How can a common place for physical and virtual spaces be formed in the practice of design?

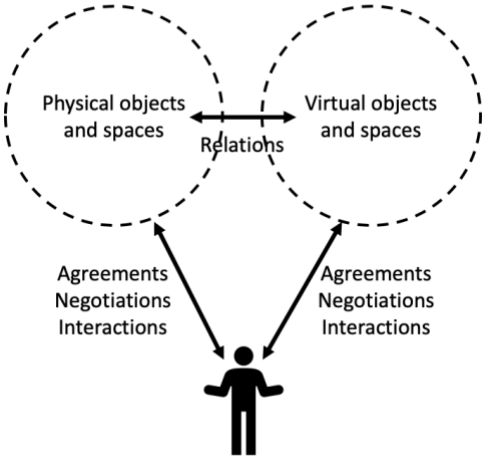


Figure 5. Interacting with Physical vs. Virtual objects and spaces

In order to address the research questions, I start with the working hypothesis based on my experiences from designer, technology and literature investigations. The assumption is that metaphor has the significant potential to connect physical and virtual space, forming a common place. In order to test the hypothesis from a theoretical perspective, I first present the theoretical background through the study of concepts that connect virtual space, physical space, place, and metaphor. In addition to theoretical study, part of my investigations is dealing with practical cases of interaction designs connecting virtual and physical spaces.

The thesis contains four introductory chapters exploring the theoretical background, then a chapter presenting the seven cases, next a chapter for discussion and conclusion, and finally a collection of the seven papers. The research questions RQ1-RQ3 are explored both in theory and practice, on different levels of abstraction. The aim of this thesis is not to produce design guidelines. The objective is to present a discussion and contribution that is relevant for both designers and design researchers involved in the development and exploration of physical and virtual spaces.

[11] I use different terms for the human agent in this thesis; observer, user, viewer, and actor. The meaning of using these terms is elaborated in chapter 3.

Research Questions Explored

The research questions RQ1-RQ3 build on each other, so that RQ1 constitutes the foundation for RQ2, and RQ2 is the base for RQ3 (Fig. 6). First, I explore the relations between virtual and physical space. Then, I investigate metaphor as a means to support the connections between virtual and physical space. Finally, I make use of metaphors, and specifically the stage metaphor, to form a common place for physical and virtual space.

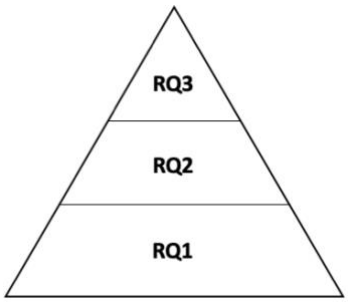


Figure 6. The research process proceeds from RQ1 to RQ2 to RQ3

This research is exploratory, descriptive, explanatory, and not normative. The aim of exploring the research questions is not to present design guidelines but to establish and motivate descriptive and explanatory models.

Here follows a list of the seven papers together with the seven cases of the thesis, for facilitating navigation and reading of the text. This is followed by a summary of how the research questions are explored, in the introduction chapters and in the papers and cases.

Papers (I-VII)

I. The Collaborative Cube Puzzle: A Comparison of Virtual and Real Environments
II. The Pelvis as Physical Centre in Virtual Environments
III. Immersiveness and Symmetry in Copresent Scenarios
IV. Staging the Interaction – Explorative Interventions for Engaging Citizens in the Development of Public Knowledge Institutions
V. The Virtual Culture House – Shaping the Identity of a Public Knowledge Institution
VI. The Transdisciplinary Nature of Virtual Space
VII. Designing For Science Centers - A Classification Framework For The Interaction

Cases (1-7)

1. Block-Box-Prism-Wedge (2005-2008)
2. Physical and Virtual spaces for Art (2007)
3. Baltic Sea Forum (2008)
4. Museum of Natural History (2009)
5. Emergency Response Center (2010)
6. Virtual Culture House (2012-2014)
7. Interactive Science Center (2016-2019)

RQ1: The Relations Between Physical and Virtual Space

Theoretically, the relations between physical and virtual space are mainly explored in chapter 3. In this chapter, I explain some of the founding characteristics of the 'physical' and the

'virtual', connecting physical to actual and virtual to potential. Here, I start on the highest level of abstraction (metaphysics) and move down to the next (semiotics).[12] A model for physical-virtual space is suggested, related to human interaction in spaces. In general, I bring up characteristics and relations with respect to *experience of space* and *structure of space*. A central concept here is *presence*, the sense of "being there", which is strongly based on experience and perception but also dependant on structure and technology. In this section, I relate to paper I, *The Collaborative Cube Puzzle: A Comparison of Virtual and Real Environments*, where a virtual and a physical version of the same setting are compared. This is done through comparing a shared virtual environment setting, using an immersive VR system networked with a desktop VR system, with cardboard coloured blocks in an equivalent physical setting (referred to as "real" in this study). Here we investigate and compare virtual and physical space through a collaborative puzzle-solving task. The main conclusions are that the VR interface matters for working in the virtual setting, and that there are differences in collaboration between the virtual and the real setting.

Further exploring RQ1 in chapter 3, I then discuss VR as an embodied medium. I use 'embodiment' in the sense that actions of the body play a role in human-computer interaction, specifically in virtual environments. Embodiment as a way to connect physical and virtual space is studied in paper II, *The Pelvis as Physical Centre in Virtual Environments*. Here, the human body and motions are analysed as a physical space and connected to virtual space, through a physical-virtual model. This model has two connection points; one physical point at the centre of mass of the human body (the pelvis), and one virtual point at the centre of watching of the human body (the eyes). This paper highlights VR as an embodied medium and also the physical-virtual space as the interaction space.

Social and collaborative aspects of virtual space are also important for exploring this research question. In this regard, I want to connect back to the pioneer projects of collaborative VR and point at some of the key aspects of "being there together". In paper III, *Immersiveness and Symmetry in Copresent Scenarios*, virtual co-presence and collaboration are studied, such that different VR technologies are combined and compared with each other and with an equivalent physical setting. Again, we use the same puzzle-solving task as in the first paper. Here, we look at immersion and presence in relation to different interfaces to a collaborative virtual space. This paper highlights the factors for presence, particularly transparency and immersion that are important factors for the sense of "being there".

This thesis is not only technical but relies also on artistic aspects. The succeeding part of chapter 3 is dedicated to the aesthetic facets of virtual space, related to visual arts, where I propose a definition of virtual space as the intersection of image space and digital space. Also, in the first two of my cases I focus on RQ1 and deal with the relations between physical and virtual from an artistic perspective, using projects from my own practice in architecture and art. The first case is a description of how both physical and virtual models contribute in the development of architectural concepts. Here, I focus on testing the design both on myself and other stakeholders, which results in new versions in an iterative physical-virtual design process. The second case is a comparison of physical and virtual spaces for visual art. Here, a semiotic analysis is made of the different spaces. In both of these cases the focus in on the research question about the relations between physical and virtual space.

Finally, chapter 3 ends with discussing this research question related to semiotics and hermeneutics. First, I introduce the theories of production of meaning in signs and sign relations, and then bring up semiotic concepts like 'code', 'floating signifiers', and 'deconstruction' that are relevant for the understanding of virtual space in relation to physical space. These discussions constitute the basis for the analysis I make in case 2, *Block-Box-Prism-Wedge*, as mentioned above.

[12] See Fig. 8 in Methodology chapter 2 for the levels of abstraction (I-IV).

Cases 3-7 are all related to RQ1 in the way that they provide examples of physical-virtual spaces, and thus constitute the material for exploring this question from the lowest level of abstraction (design) and up. The general approach is that I discuss the different agreements and negotiations that users need to make with the physical objects and spaces versus the virtual objects and spaces respectively. My ambition is that the diversity in context and the similarity in relations and conclusions highlight the key aspects of this research question. Simultaneously, these cases also work as platforms for investigating RQ2.

RQ2: How Metaphors Support the Relations Between Physical and Virtual Space

The research question about how metaphors, and specifically the *Stage* metaphor, support the relations between physical and virtual space is theoretically explored in chapter 4, mainly on the higher levels of abstraction. The concept that I investigate is that a space becomes a place through human connection, and then that a place can become a stage through common agreements and metaphors. Therefore, I first establish the relations between space and place, stating that 'place' is the concept that connects 'space' with 'stage'. In doing so, I also connect structure of space with human experience and interaction.

Then, I focus on metaphor (metaphorically speaking; actually, I am just writing about metaphor in this particular section of the thesis, using the 'focus' metaphor to transfer meaning from 'seeing' to 'writing'). The founding notion here is that metaphor is a powerful way to support agreements being made between users/actors and spaces, create meaning in the sign process, and frame the conditions for human interaction. I present some of the founding notions of metaphor, including *seeing as*, *conceptual metaphor,* and *production of discourse*. These are then the concepts I use in order to introduce the *stage* metaphor.

In order to further explore this research question, especially on the intermediate levels of abstraction (from philosophy of design to semiotics), I present the central concepts of theatre; scene, drama, stage, performance, role, etc. The ambition here is to put forward the concepts of theatre and the process of stage design as relevant ideas and approaches for connecting physical and virtual spaces. A discussion around the concepts 'almost real', 'more than real', and 'as if' are done to support this.

In my pursue of RQ2 on the lower levels of abstraction (from design to philosophy of design), I use the concept of *staging* for relating the stage metaphor to the actual physical-virtual settings of my projects. Three of the papers explore the stage metaphor through staging. In paper IV, *Staging the Interaction,* staging is explored with a societal perspective. Here, the interaction between municipality and citizens is staged in a participatory design process, in close collaboration with different stakeholders of a community. In this study, VR becomes the catalyst for the development of a public institution. Staging of virtual public spaces is studied in paper V, *The Virtual Culture House – Shaping the Identity of a Public Knowledge Institution.* Here, the cultural expressions and activities of a community are staged in a virtual platform, where the participants become both actors and audience. In the most recent paper VII, *Designing for Science Centers - A Classification Framework for the Interaction,* I explore the staged interaction between visitors and content in a science center.

These papers are strongly connected to cases 6-7, where more emphasis is put on staging as a way to connect physical with virtual. Case number six is the *Virtual Culture House*, a project aimed at creating a higher level of participation from all stakeholders in the process of realizing a new culture house. The Virtual Culture House is a dynamic space for the dialogue between different stakeholders in the development process of the physical culture house. The seventh and final case is the *Interactive Science Center*. This case highlights the relations between physical and virtual spaces in science centers. These relations are investigated by staging the interaction between visitors to the science center and the science content, using physical-virtual spaces.

In the third case, another strong conceptual metaphor is introduced. This case is the *Baltic Sea Forum*, a science center for research, education and "popular science" presentations on the island of Gotland, Sweden. Here, I contribute to the design process by introducing the *surface* metaphor, which derived from seeing the space as a stage.

Case number four is the *Museum of Natural History*. The exhibition features stuffed animals, plants and other items, combined with poster images and texts that describe the objects. The building has a sequence of spaces with different characteristics and set design that together form the unified experience of the museum. The management has decided to renew and partly transform the exhibition and thus integrate virtual representations of environments, maps, models, etc. In this case I study the on-going process of the development of the museum, and also propose a set of possible virtual spaces as overlay to the physical.

The fifth case is the *Emergency Center of Gothenburg*, where an emergency center room is located. This space has its physical properties combined with a number of virtual spaces (projections, screens etc) that altogether form a physical-virtual space, where actors with different roles can be present in physical, virtual and mixed physical-virtual spaces. My stance in this case is firstly to contribute with the perspective of seeing this situation as a physical-virtual stage.

RQ3: How a Common Place for Physical and Virtual Spaces Can Be Formed

This research question is explored theoretically in chapter 4, given empiric material in chapter 5 (Cases), and then answered and summarised in chapter 6 (Contribution and Discussion). My motivation for this disposition is to address the question on different levels of abstraction. Chapter 3 provides with the conditions for forming a common place, by stating the characteristics and relations between the physical and the virtual. In Chapter 4, I introduce the concept of the theatre stage as metaphor for this common place I call *A Seeing Place.*

In relation to RQ3 on the level of design, all the seven cases work as examples of how physical-virtual spaces appear in a variety of contexts, and how these situations can be approached as design problems. A common aspect of the specific design problems is that there seems to be no unifying concept that works well for both the virtual and the physical parts of the design context. For example, in both cases 3 and 4, *Baltic Sea Forum* and *Museum of Natural History,* there are separate design teams assigned with designing the physical and the virtual spaces, with different requirements and conditions. In case 5, *Emergency Center of Gothenburg*, there is no unifying concept of how to form a physical-virtual space.

Forming of a common place for the physical and the virtual is explored on a higher level of abstraction through the concepts of transdisciplinarity and virtuality in paper VI, *The Transdisciplinary Nature of Virtual Space.* This paper aims to contribute to bridging the gap between the two separate academic cultures, the sciences and the humanities, using Virtual Reality with its spaces as a transdisciplinary platform. I argue that *Philosophy of Nature*, a synthesis of science and philosophy, is vital as an approach in the forming of a common place for the physical and the virtual. Transdisciplinary research strategies cross disciplinary boundaries to create a holistic approach and apply to research efforts focused on problems that combine multiple disciplines, as in the scope of this thesis. Here transdisciplinary research, especially where philosophy meets science and art, can contribute to the recreation of natural philosophy.

In chapter 6 (Research Questions Revisited) the contributions are summarised and discussed. I present *A Seeing Place* as a model for connecting physical and virtual space on a common stage. In addition to the presented reflections and results, this model is the main contribution to RQ3.

State of the Art of Research on Virtual Space

From the first fiction book mentioning VR-like glasses in 1935, via first multimedia VR devices in 1957, first head-mounted displays in 1968, and first mention of the term 'Virtual Reality' in 1987, the VR has developed as a flourishing research domain over the last decades (Poetker, 2019). This domain includes mainly visualization, interaction design, computer graphics, and media, but is also related to psychology, cognitive science, visual arts, architecture, and philosophy. Recent surveys of research on virtual space (Fayard, 2012; Malecki, 2017; Saunders et al., 2012) suggest that exploring the relations between physical and virtual space, and between users and spaces, is important and needs more study. In the 2010s, publications like *Making Sense of Space: The Design and Experience of Virtual Spaces as a Tool for Communication* (Kuksa & Childs, 2014) have made extensive surveys and explanations of the central concepts of VR and virtual space, highlighting that this is a quite novel and still developing research area.

A common approach for studies on virtual space is to focus on *presence*, the sense of being there, and *immersion*, referring to the level of submergence of a user within a virtual space. The article *A Survey of Presence and Related Concepts* states that "The presence construct, most commonly defined as the sense of 'being there', has driven research and development of virtual environments (VEs) for decades" (Skarbez et al., 2017). This approach builds on earlier studies of psychology (Schuemie et al., 2004) and media (Moser et al., 1996) and is still valid today in research on psychology (Diemer et al., 2015), cognition (Zhongmin & Wenhong, 2018), human factors (Piccione et al., 2019; Tussyadiah et al., 2018), and visual communication (Arya, 2019). These studies indicate that realism, in the sense of perception of the environment and real-life-like bodily movements and interactions, leads to higher sense of presence and better immersion. They also suggest that higher sense of presence and higher level of immersion have positive effect on performance in the virtual space, however this seems to be quite context dependant. It is evident that more research is needed in this area, especially when it comes to connecting virtual space to physical space.

From a design perspective, the relations between physical and virtual spaces and objects are studied in the domain of interaction design, through design research projects where users interact in co-existing virtual and physical spaces (Clergeaud et al., 2017) and with separate settings used to compare the 'real' and the 'virtual' (Brade et al., 2017). Different methodologies have been developed for designing virtual environments and applications (Polcar et al., 2016). This research suggests that there are both similarities and differences between designing for the physical vs designing for the virtual and that more research is needed. Adaptations of 'real-world' situations into virtual settings are also a topical design research area. For example, in online learning, a variety of 'virtual classrooms' are being developed and investigated. The article *Virtual worlds: A new environment for constructionist learning* (Girvan & Savage, 2019) concludes that "appropriating emerging technologies for constructionist learning requires us to move beyond simply replicating traditional constructionist tools and environments and instead requires us to be open to new and unexpected potentialities of the technology to transform constructionist learning". Statements like this highlight the potentiality of expanding and transforming existing physical settings using virtual spaces in innovative ways, where new concepts would contribute.

The concept of 'stage' has been discussed in Virtual Reality already since Char Davis presented her famous virtual art installations (Davies, 1998). In more recent research, 'stage' is explored for its potential to highlight certain aspects in a virtual environment, as in the article *The Place Metaphor in 3D CVEs: A Pedagogical Case Study of the Virtual Stage* (Prasolova-Førland & Wyeld, 2008), where role playing is scrutinised in a theatre play on stage in a collaborative virtual environment (CVE). Studies like this show that the stage is well suited as a place for making new agreements, also in virtual space. Recent VR projects are using the physical stage

as an edge-case for prototyping the integration of high-end digital visual features with traditional analogue crafts for décor and costumes (Chamberlain et al., 2017; Honauer & Hornecker, 2015; Zhang et al., 2017), emphasising the challenges of merging the physical and the virtual. Stage is also connected to 'staging', which has become topical as a method in interaction design for putting something metaphorically 'on stage' in different contexts (Roussou & Katifori, 2018).

On the higher levels of abstraction, virtual spaces are also of interest for philosophers and theorists of architecture. Philosopher David Kolb argues in the article *Real Places in Virtual Spaces* (Kolb, 2006) that "Real events happen in real places in virtual spaces". His argument is that it is the human actions in and human connections to a space that define it as a place, regardless of the materiality of the space. The relations between the physical and the virtual are being discussed using theories from philosophy and semiotics. For example, the paper *The Present Tense of Virtual Space* (Burrell, 2018) investigates "the role of memory and imagination in our understanding of, and in relation to, virtual environments as phenomenologically real spaces", leading to the notion that Virtual Reality is also real and that memory and imagination play important roles in our perception of the world, regardless of virtual or real.

The potentiality of virtual space to create and support new agreements between human and space is also highlighted in semiotic analyses of virtual spaces. For example, the article *Semiotics of virtual reality as a communication process* (Barricelli et al., 2016) states that concerning realism "This goes beyond being faithful to the physical values of the reality to depict: the simulation has to be faithful to its spatial representation". Contemporary studies seem to support the notion that the duality between virtual and real does not exist and that human perception of virtual and physical space is the same, from a phenomenological perspective. However, it is evident that this area of philosophical investigation regarding the relations between physical and virtual space have room for further exploration, including the philosophy of senses. The same goes for cognitive science and neuroscience as frameworks for explanation of the process of generation of subjective feeling of reality or virtuality.

This summary of state-of-the-art research justifies my research questions as topical and relevant subjects of further investigation. It can be noted that today's research on virtual spaces is often done within multi-disciplinary projects, involving expertise from related domains such as psychology, cognitive science, visual arts, architecture, and philosophy. What seems to be lacking are common models that involve physical and virtual space, the actor/user, and a place for the interaction, where these models incorporate perspectives on multiple layers of abstraction from hands-on design work to abstract metaphysics. I argue for the necessity of a research that:

1. Investigates the relations between physical and virtual space on multiple levels of abstraction,
2. Uses a transdisciplinary approach for cross-domain mappings between multiple domains, and
3. Gives gestalt to these relations in models.

2. Methodology

This work is based on a transdisciplinary research approach that uses a variety of methods, both theoretical and practical. Its approach spans between knowing and making/constructing, and between abstract and concrete. Typically, the ideas and hypotheses are investigated in relation to a specific context (case), then analysed, synthesised, and realised. This approach resembles an innovation process, such as explained by Vijay Kumar (Kumar, 2003). He frames it as a two-by-two matrix, starting in investigation (Research in Fig. 7) leading to insights through analysis, further to concepts by synthesis, and then to implementation (Fig. 7). From this delivery phase, process continues to the next turn/reiteration in a spiral. Kumar explains in his model that "'Framing Insights' are primarily about descriptive modelling, creating abstract mental pictures about the patterns that we find in reality. 'Exploring Concepts' and 'Making Plans' are about prescriptive modelling."(Dubberly et al., 2008) These descriptive models are framed in the analysis of space in this thesis, and then conceptualised through synthesis and realised as prescriptive models. In the cases presented in this thesis, the models are related to different contexts, where they are discussed and questioned.

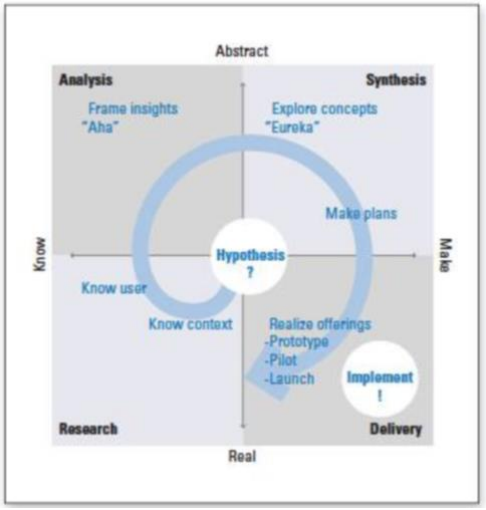


Figure 7. Kumar Model. The research-analysis-synthesis-delivery model
(adapted from Dubberly, Evenson, and Robinson, 2008)

On a third axis with respect to Kumar model of the research process, my work has different levels of abstraction (Fig. 8). This model follows the method of *Layers of Abstraction* as applied in science, engineering, and philosophy (Floridi, 2008). In this method, a set of separate layers is identified, where a system can be analysed at different layers in relation to discourse. These analyses generate models that identify the structures of the system. The steps in this hierarchy can be called layers, levels, or degrees. I have chosen the term 'levels' as it emphasizes the levels of detail vs overview.[13] On the basic level, the research topic of this thesis is *design practice* with design evaluations. Here design solutions are discussed and related to pros and cons in different settings. In the next, higher level of abstraction layer, the focus is on *philosophy of design*, that is the definitions, foundations, and implications of design. This is where Latour's hybrid, Barthes' death of the author, McLuhan's medium is the message and other fundamental theories about creation, gestalt, and representation are discussed. Above this layer, there is a theoretical layer of *semiotics* (theory of signs and sign relations) and *hermeneutics*

[13] Level of abstraction, as defined by PC Mag Encyclopedia: "The amount of complexity by which a system is viewed or programmed. The higher the level, the less detail. The lower the level, the more detail." (https://www.pcmag.com/encyclopedia/term/level-of-abstraction)

(theory of interpretations). Here, the production of meaning is discussed, through the semiotics and hermeneutics methods. On the top layer, this thesis has a *metaphysical* level of abstraction. Here, the fundamental philosophical questions of space are discussed with the focus on potentiality and actuality, connecting to virtual and physical space.

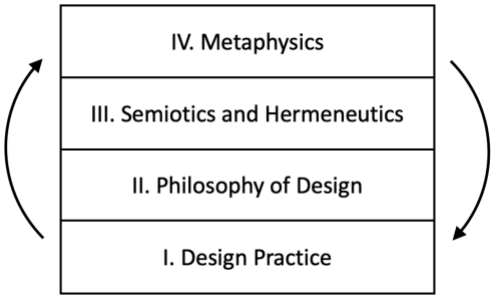


Figure 8. Levels of abstraction (I-IV) in the methodology of the thesis

These are the identified levels or layers of this research. They illustrate the transdisciplinary research approach of the thesis and how different involved research domains mutually relate. Research problems in complex phenomena, such as virtual space, present a wide range of aspects and facets that may be approached differently at different levels of abstraction.

Transdisciplinarity in Relation to Natural Philosophy

Nicholas Maxwell explains in his *In Praise of Natural Philosophy* how transdisciplinary research has been lost, and how vital it is for the scientific communities to find their way back to the ideals of natural philosophy (Maxwell, 2012). Transdisciplinary research strategies cross disciplinary boundaries to create a holistic approach and apply to research efforts focused on problems that combine two or more disciplines. Here transdisciplinary research, especially where philosophy meets science, can fulfil the "need to recreate natural philosophy – a synthesis of science and philosophy"(Maxwell, 2012). The development of contemporary natural philosophy is encouraged by the possibilities of quick and efficient communication among different scientific, humanistic and cultural disciplines which made visible the pressing need for better understanding and common semantics. Nowadays there is an alarming division and separation of knowledge fields that live in their isolated worlds, without awareness of each other. This fragmented understanding of the world presents a problem for the further development of sciences, humanities and arts. Many have already identified worrying lack of common understanding that affects our possibilities to act adequately.

This thesis aims to contribute to bridging the gap between the two separate academic cultures, the sciences and the humanities. On one hand physics, chemistry, biology, astronomy and computer science, and on the other literature, history, philosophy, art and art practice. It is hard to find a more resistant division in the academic world, than the mutual alienation of natural scientists and humanists. Even though there are cross-disciplinary initiatives, committees and projects at the universities, there is a lack of common ground and overlap in research and education. As Maxwell argues, there is a need for transdisciplinary domains where natural science and human science come together. There are two distinctive ways to achieve this. The first is to describe and discuss one domain in the terms of the other. Here the lack of knowledge of the other's domain-specific language becomes problematic. As pointed out by C. P. Snow in *The Two Cultures* it is hard for a physicist to discuss literature without knowing Shakespeare, and it is likewise hard for a historian to discuss physics without any knowledge of the laws of thermodynamics (Snow, 1964). Academic language is different in the

two cultures, both in terms of writing and reading texts. Also other representations of knowledge, such as images and figures are different in different domains (Elkins, 2008).

The other typical way to achieve transdisciplinary research is to find or create new domains that embrace multiple domains. Here natural scientists and humanists can meet on equal terms. Without common ground and knowledge in each other's literature, the conversation can instead take place in a third discipline providing shared conceptual framework. One such transdisciplinary effort is the theory of *Conceptual Spaces* (Gärdenfors, 2004) that takes stance in linguistics and philosophy, and then strives to explain how cognitive processes work in relation to evolution and the world around us. In the evolving area of AI, natural sciences and human sciences have come together in the development of new knowledge, where computer science meets cognition and philosophy. In such novel research domains, creating ideas through speculative thinking and qualified guessing, based on connections between different domains and extrapolations of known facts, is an important part of the progress of knowledge generation. This thesis reflects on the potentiality of virtual space for new natural philosophy, connecting relevant concepts from different domains.

Concurrently with the tremendous developments of research and technologies, an emerging phenomenon of virtual space is winning new grounds. The understanding of virtual space requires new insights in the relations between human and space, from philosophical, cultural and artistic, as well as technological and scientific (cognitive, biological, neuroinformatic, etc.) point of view. This thesis investigates an understanding of virtuality through a transdisciplinary approach, where sciences meet philosophy. The methodology originates in semiotics and hermeneutics, connecting the production of signs with a human-centred view on interpretation and creation. The focus on 'space' is motivated by its wide range of connotations and applications in different research disciplines and practices. Space is here used as a concept for the structural properties of an entity where objects and events are related. Space is the conceptual framework that gives the conditions for these relations, while at the same time being constituted by these relations.

This thesis presents virtual space as a transdisciplinary stage for natural philosophy. It can facilitate the process of recreating natural philosophy as a synthesis of sciences and philosophy, and enable adding cultural aspects coming from arts and other domains of knowledge broadly construed. Here the contemporary phenomenon of virtual reality with its virtual spaces provides a platform for conceptualizing natural philosophy through multidisciplinarity. In order to support this idea, the thesis investigates an understanding of virtuality through a combination of natural sciences, cognitive science, philosophy, and art. The aim is to show how these different perspectives come together in a holistic view of virtual space.

The Aesthetics of Science

From the ancient time of Aristotle, via Newton, Leibniz and Kelvin, natural philosophy or philosophy of nature was the philosophical study of nature and the physical universe, where universe was synonymous with "reality" (Jammer, 1954). With the development of new technologies as well as new scientific methods including simulations and advanced visualisations, the immediate connection between the observer and the world "out there" has become increasingly complex (Rössler, 1998). More and more of information we perceive about the world is heavily "pre-processed", it is also entering complex associations with other knowledge. Thus, increasing part of information in our knowledge about the world is not directly perceived but is mediated through steps involving instruments and equipment including computers that transform original data observed "in the world". With the computer technology of today we have the possibility to both dig deep into the microscopic world and see the big macroscopic picture, and also connect different areas of knowledge belonging to various domains and levels of abstraction. This means that a deeper understanding of images and virtual spaces as an interface to the world becomes important for natural science.

Natural science has always been subject to aesthetic concepts such as symmetry, harmony, simplicity and complexity, and aesthetic values such as finding beauty in nature and the beauty of truth (Ivanova, 2017) These aesthetic concepts and values create subjective relations between the scientist and the science. Today the connections between science and aesthetics go even further and are more concrete, with the increased use of advanced visualizations in science. These visual representations have developed from simple graphs to images, animated images, simulations, and virtual environments. Advanced visualizations are increasingly becoming the interface to the world that is observed in science. As such they are developed in a design process that includes decisions about colour, framing, grid, perspective, etc., using the aesthetic concepts of symmetry, harmony, parsimony and similar. This also means that these images and spaces are related to other images made and thus part of our visual culture. What is observed by the scientist is perceived logically and rationally but also intuitively through various filters of senses and aesthetic judgement. The visualizations are not only representations of data and relations but also carriers of aesthetic, artistic qualities. They have become a medium for representing and exploration of data generated by observations/ measurements and theoretical models.

Also, the multimodality of these interfaces has become richer in the use of not only visual, but also auditory and haptic interfaces, turning them into multimodal interactive virtual spaces. This development of virtual spaces is a result of transdisciplinary progress in technology, sciences and arts. Virtual spaces are as such not only technological constructions with functional purposes but also designed artifacts, and subject to values and aesthetics.

Analytical Approach

The investigations of physical and virtual space, concepts of space and place, metaphors in relation to space, and the stage metaphor contain theoretical part based on literature studies and practical observations and interventions including works of architecture, art and design. This observational material has been used for reasoning, analysis and synthesis reflecting back to the theory. The approach consists of a theoretical development, where the observations are analysed and then synthesised in conceptual models contributing to the theory. This research is exploratory, descriptive, explanatory, and not normative. In this thesis I have divided the theoretical development in the following sections:

1. Transdisciplinarity and relations to Philosophy of Nature
2. Virtual and Physical Space and Place
3. The Stage Metaphor

In the first section, where transdisciplinarity and philosophy of nature is studied, the method consists of literature studies from different domains connected through the concept of space. The analysis is based on reasoning on spatial aspects in science, humanities, and aesthetics. In the second section, dedicated to virtual and physical space and place, the method is more diverse. The analysed material includes literature, related design work, and my own design work in virtual reality and architecture. The method aims at synthesising the analysis and forming conceptual models of the relation between physical and virtual space. In the third section, where the stage metaphor is investigated, another literature study is done with the emphasis on theatre.

These analyses are done through semiotics (sign-based analysis) and hermeneutics (interpretations-based). These two theories and methods complement each other and give two different perspectives. While semiotics is dedicated to the meaning as structure for an observer, hermeneutics is dedicated to the meaning as understanding of an interpreter.

Semiotics is both a theory and a method for analysis of signs. In semiotics, cultural, societal and natural phenomena are explored as signs, where the fundamental question is how

meaning is formed. Semiotics explores the content of signs, their use and the formation of meanings of signs at both the level of a single sign and the broader systems and structures formed by signs (Silverman, 1998). Semiotic methods approach signs as existing in various forms: pictures, words, gestures, objects, phenomena and actions. Using semiotics as method, the aims are to understand and interpret signs, and the interaction of signs and sign systems. The purpose is to analyse the construction rather than the understanding. In the semiotic analysis, the signs and use of signs are seen as a part of a sign system that forms the use of the signs. As such, the system always has an effect on the contents of individual signs and a sign is never independent of the meanings and use of other signs. Semiotic methods use both qualitative and interpretative content in the analyses.

Semiotics is used as method for example in Case 2, *Physical and Virtual Spaces for Visual Art*. This case starts with a semiotic analysis of visual art in relation to virtual space, connecting them through sign relations. The four spaces of the case are analysed separately and then compared regarding the production of meaning through signs and sign relations. Semiotic concepts and terms, such as signifier and signified, triad, object and interpretant, and code, are used to analyse and synthesise these spaces.

Hermeneutics is both a theory and a method for text interpretation. This 'text' can be in any form; written text, images, sounds, or other media. "Hermeneutics is more than interpretive principles or methods we resort to when immediate comprehension fails. Rather, hermeneutics is the art of understanding and of making oneself understood." (Zimmermann, 2015). I will also refer to the text as object (design, piece or work of art) in the context of this thesis. Hermeneutics opposes to the mechanical and structuralist concepts of semiotics and focuses on the interpretation and the relation between the object and the viewer. When using hermeneutics, interpretation is seen as a dialogue between the text and the interpreter (Prasad, 2002). This standpoint towards the author is known as "the death of the author" (Barthes, 1977). In his well-known essay, Barthes argues against the method of reading and criticism that relies on aspects of the author's identity to extract meaning from the author's work. Barthes's essential argument is that the author has no authority over his own words (or images, sounds, etc.) that belong to the reader who interprets them. Readers must thus, according to Barthes, "separate a literary work from its creator in order to liberate the text from interpretive tyranny" (Barthes, 1977). Again, this also applies to other forms than written text.

In the cases presented in this thesis, semiotics and hermeneutics are used as methods for analysing the designs. Here, I use metaphors to connect semiotics with hermeneutics. In semiotic terms, a metaphor involves one signified acting as a signifier to another signified, meaning that a metaphor consists of a primary subject (tenor) expressed in terms of a figurative secondary subject (vehicle) (Richards, 1936). From the perspective of hermeneutics, a metaphor adds meaning and flavour to the text. In design, metaphors work as heuristics that help organise design thinking and make designs understandable (Antoniades, 1992; Rowe, 1987). For the designer, metaphorical reasoning is an iterative process through which designers gradually increase their understanding of a design situation. With the use of metaphors in my design work and in the analysis of design, the aim is to connect the structure of the design (semiotics) with the understanding of the design (hermeneutics).

Semiotics as method is used in Case 1, *Block-Box-Prism-Wedge*, where the four conceptual shapes work as vehicles for the primary architectural subjects. Simultaneously, they create meaning to the design in the way they organise the thinking and increase the knowledge of the design. The method to use metaphors is therefore a way to integrate semiotics with hermeneutics in this context of architectural design.

The method in Case 3, *Baltic Sea Forum*, is to introduce a metaphor for the architectural space, seeing the barn as a stage. From there the "surface" metaphor and more metaphors are introduced, giving meaning to this stage. The metaphor introduced in Case 5, *Emergency*

Response Center, is space as a "blob" or "bubble", where the physical space could expand through the windows into the different virtual spaces.

In Cases 4, 6, and 7, where museums and science centers provide the context, the stage metaphor is introduced through the concept of "staging the interaction". The idea is that a stage is a place for staging, that is presentation of a scene, a drama, or a performance. Stage is here used metaphorically, with the intention to open up the physical-virtual space for a way of seeing users as actors, the space as a stage, the limitations as a set, events as part of a drama, clothes as costumes, and so forth.

Design Approach

This work aims to contribute to the design practice and design theory of virtual vs. physical space by reflecting on concrete design cases and examples in the light of semiotic and hermeneutic theories. The research is conducted in the interplay/interaction of creative design work and reflective design investigation. This involves a set of related design methodologies; practice-based research, action research, design research, research by design, and constructive design.

My contributions to the design in the seven cases are based on the methods of *action research*, which is used to generate solutions to practical problems (Meyer, 2000). Action research involves the process of active participation in a situation where there is a change or development in an organization or a project. As a researcher, I focus on "my own" actions, discuss my participation in the group, and reflect on the cases with an aim to generalise the results in a theoretical context. In my work I tend to emphasize on the latest perspective to let the cases, my own design contributions, and the theoretical models mutually inform each other. However, even though action research projects typically rely heavily on qualitative data in the form of recordings and interviews focusing on the participants and their experiences, my method is more distanced from the participants and focused on the structural aspects of the cases.

The strong connection to the practice of design and architecture necessitates the method of *practice-based research*, where original investigation is undertaken in order to gain new knowledge by means of practice and the outcomes of that practice (Candy, 2006). In *practice-based research in art and design* artists and designers develop their own methodological approaches to problems, which are different from other scientific approaches. It can be said that both knowledge and method in this research are interdisciplinary hybrids, making the work a product of interactions of different standard disciplines, such as artistic research, architectural, technological, design, scientific, and philosophical.

The research area of *Digital Representation*, that my work belongs to, has its base in *artistic research*, where artistic work is created and reflected upon through a process that connects artistic practice and theory (Hannula et al., 2005).

The probably most widespread research method in computer science is called constructive design, also known as exploratory research (Shields & Rangarajan, 2013). Using IT and electronics as a design material makes this method relevant. Application of the method begins with defining a relevant problem, and then a solution is constructed using theoretical foundations. The solution is then evaluated in dimensions and conditions that are appropriate for the problem or the domain of the applied solution. Evaluation aspects in constructive design are, for example, performance of an approach as well as accuracy or completeness of the produced results. In my work, these evaluations are done from qualitative data.

The areas of artistic research and design research are constantly developing and maturing in the use of new technologies, tools and theoretical references. In this thesis variety of methods are explored in the presented cases. The motivation is that more meaningful knowledge in this context can emerge by triangulating between related methodologies rather than following one approach in all cases (Flick, 2009). The challenge is then of course that the

results in the different cases are more difficult to compare. However, as this thesis spans over natural sciences, human sciences, art and design, a wider range of methods is required in order to provide a deeper understanding as well as a better overview.

Transdisciplinary Design Research

Transdisciplinarity is a reflexive research approach that addresses problems by means of interdisciplinary collaboration as well as the collaboration between researchers and extra-scientific actors (Jahn et al., 2012). The transdisciplinary approach of this design research is not only theoretical but also practical. In the cases presented in this thesis the teams of designers and researchers, in which I have participated, have been quite diverse in terms of expertise. One of the main challenges has been to bridge over the different domains using the research case as common context.

Especially in cases 3, 4, 6, and 7, dealing with public knowledge institution, the teams have included scientists from different domains, as well as educators, designers, project managers, and decision makers. The *Baltic Sea Forum* project had a strong natural science aim, where marine biologists and oceanography experts set the agenda for the content of the planned science forum. The project team was then led and organised by project managers and decision makers. So in this team, there was a lack of both pedagogy and design expertise, setting challenging conditions for how to go from investigation, via analysis and synthesis, into realisation, in relation to the Kumar Model. In the *Museum of Natural History* case, the situation was quite different. The museum had been relatively unchanged for more than a century and the challenge was to transform the existing exhibitions using new media and technology. The main challenge here was the contradictory views the team of biologists, conservators, pedagogues, museum guides, and management had on how (or if at all) this transformation should happen. In the *Virtual Culture House* case, the team had a core of municipality district management, supported by librarians and other municipality staff, and then advised by researchers and designers, with a citizen participation approach. The *Interactive Science Center* case had a diverse team of natural scientists from different domains, educators, designers, project managers, and decision makers. In all of these cases, the main challenge was to create common ground and mutual understanding for making good decisions.

My roles have also shifted between the different cases. In cases 1 and 3 I was the architect; in the *Block-Box-Prism-Wedge* case in a two-person team of architects developing architectural concepts, and in *Baltic Sea Forum* commissioned as the architect to a multi-disciplinary development project. In case 2, *Physical and Virtual Spaces for Visual Art*, I was not involved in a research or design team but rather had the role as the observer. In cases 4 and 5 (museum and rescue center) my role was also mainly observing but in contact and dialogue with the teams. In the *Museum of Natural History* case I participated as visualization expert in project meetings about the transformation process, and in the *Emergency Rescue Center* case I participated as a design researcher to give input and was shown the facilities and explained how the spaces were related and what challenges they had. In cases 6 and 7 (culture house and science center) I was the interaction design specialist and teacher, both contributing with my own expertise but also leading the interaction design master student teams. In the *Virtual Culture House* case my role, shared in a two-person team, was to support the municipality district with advice on how to involve the citizens in a participatory design and development process. I then transferred this process to the classroom, providing the interaction design master students with the project framework and context. In the *Interactive Science Center* case I had a more central role, both deciding on the different project themes and leading the interaction design master student teams.

Research by Design

Traditionally, creation and investigation, or design and research, has been seen as two different and separate lines of work. However, in the rise of interaction design (Cooper et al., 2007) and the new renaissance of multidisciplinary research (Maxwell, 2012) a community of research *and* design has emerged. The research communities of *research by design* (or research through design) and *design research* (or research for design) have, in the last decades, started to build up a strong foundation of knowledge connected to both theory and practice. The methodology for creating theoretical knowledge through design work is *research by design*. New knowledge in the intended domain is created through design work in the given context. Research by design can be seen as abstracting "what is" to form new constructs, and then aiming at realising these into "what could be", as described in the Robinson model (Fig. 9). Here the methodology is balanced between inspiration-based design research and investigation-based design research (Sanders, 2005), where knowledge is built upon experimentation in combination with investigation. As such, the methodology relies on the designing of prototypes as a generator of knowledge (Stappers, 2007). In the *design practice community*, the term *design research* generally refers to grounding, informing and inspiring the product development process. However, in the *design research community*, the term implies an investigation focused on producing a contribution to knowledge. My work follows the convention of design researchers, with the intention to produce knowledge rather than to inform the development of artifacts/products. The designs that are developed and discussed in this thesis are reflected in a theoretical framework, where an analysis is made based on semiotics and hermeneutics. This research method is descriptive in the sense that it shows the state of design practice in relation to theories about communication, sign relations, and interpretations. On the other hand, this method has a normative aspect, since it strives to "make the right thing", an improvement that transforms the world from its current state to a preferred future state (Zimmerman et al., 2007).

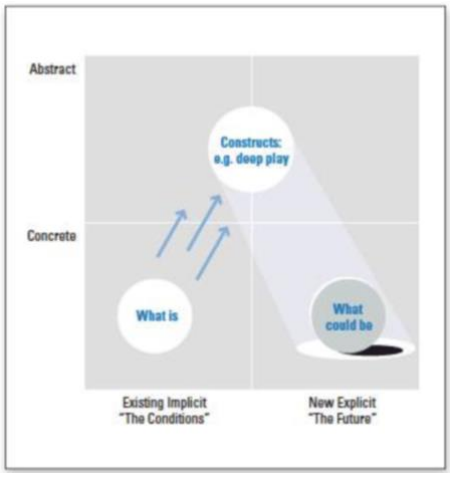


Figure 9. Robinson model. The analysis-synthesis bridge model
(adapted from Dubberly, Evenson, and Robinson, 2008)

In my early work in Virtual Reality, such as *Virtual Molecules* (A.-S. Axelsson et al., 1999) and *Cubes in the Cube* (Wideström et al., 2000), research was done through design contributions in different research projects in Virtual Reality and Technology and Society. The virtual molecules could have been represented in various ways, but the specific design with its shape, size, colour, and use of sounds, defined the conditions for the case study. It was my design of the Rubik's cube-like puzzle that set the stage for comparing the interaction, collaboration, and performance in the physical vs the virtual setting. The cube puzzle was designed, not only as a practical solution to the problem of creating a collaborative task, but also to work as a

metaphor communicating different connotations of the puzzle, such as "problem", "intelligence", and "solution". This was a specific design solution to a design problem that then led to general knowledge about co-presence in different multi-user scenarios. My method here was to listen in with the research team and create a design solution that would live up to their requirements, and at the same time contribute as a designer with more than they expected. As such, the presented prototypes created knowledge, not only theoretical knowledge for the research project but also practical knowledge for me as a designer of virtual environments. In the *Virtual Icosahedron* project (Wideström & Muchin, 2000) the research was done through a more collaborative design work, where the prototyping process was iterated together with the research team.

Architectural Design Methods

My architectural work presented here, such as *Block-Box-Prism-Wedge* (see Case 1), show how virtual and physical prototyping can contribute to the architectural design process. Here, the method was to let the prototypes lead the way in the production of knowledge in a *research by design* process. The work in this case was done by iterations of designing, evaluating and re-designing in a two-person design team, going back and forth between physical and virtual representations of architectural concepts. The four shapes that crystallised from this process became founding metaphors that were used as core concepts in the architectural projects in the years to come. Furthermore, the *Baltic Sea Forum* project (see Case 3) show how a strong design concept based on a metaphor could transform the organisation's understanding of their own project. The method was again to listen in with the team of scientists and project managers and then present a design concept that was more (or at least other) than they expected. The work in this case was very much grounded on inspiration-based design research, where the action came before the reflection.

Design Research Methods

In the cases of *Physical and Virtual spaces for Art* (Case 2), *Museum of Natural History* (Case 4) and *Emergency Response Center* (Case 5) a more design research approach is used. The research is more focused on investigating the design, giving me the role of the reader rather than the author.

Research-based Design

The most recent cases, *Virtual Culture House* (Case 6) and *Interactive Science Center* (Case 7), show how virtual and physical spaces co-exist and intertwine, through staging of the interaction between actors and content in public knowledge institutions. Here, the stage metaphor is used, both as the founding design concept and as the ruling concept for the analysis. This means that the methodology is balanced between inspiration-based design research and investigation-based design research. The method is based on designing prototypes as a generator of knowledge, built upon a combination of experimentation and investigation.

Common Design Context

As design contexts, Case 2, 3, 4, 6, and 7 share common conditions. They are all public knowledge institutions of different forms; science centers, museums, and a culture house. This means that the designs are related to the general public of different user groups that are supposed to experience and interact with the displayed content. The design method in this context is to stage the interaction between the content and the user in different exhibits that are supposed to come together in an overall experience of artistic, scientific, or cultural work.

3. Virtual and Physical Space and Place

This chapter explores my first research question, RQ1, the relations between physical and virtual space, and analyses a wide range of aspects on different levels of abstraction (I-IV as described in Fig. 8). The ambition is to contribute to a deeper understanding of contemporary multi-modal digital spaces and their relations to our physical spaces and ourselves as users.

Actual Physical Space

Through the history of humankind space has been experienced and investigated in different ways, in the traditions of a variety of specialist fields. Space has been measured in distance, connected to real-time and related to motion, through explorations in natural sciences. Space has been the subject of extensive research and literature, where philosophy is deeply connected to physics (Jammer, 1954). The fundamental concepts for space created in the 17th and 18th centuries (by Leibniz, Newton, Kant and others) have formed our knowledge of space to this day. From these theories 'space' can be seen as an abstract and discrete set of objects and voids formed by relations, a continuous and measurable entity formed by forces, or a synthetic framework for organizing experiences. Modern physics has then led to concepts of the four-dimensionality of the spacetime. In classical physics, the 'theatre' metaphor of space and time determines the exact location and speed of a particle. In contemporary physics "there is no longer space which 'contains' the world, and there is no time 'in which' events occur" (Shapiro, 2019). Contemporary neuroscience suggests that space and time are mental constructs, and that spatial and temporal relations are conceived without actual brain representations of our pre-conceived ideas of space and time (Shapiro, 2019). It is the combinations and relations between these different explanations, theories and models that have formed our understanding and knowledge of space.

However, the scientific and philosophical theories do not cover all our understanding of space. Space has also been explored culturally and understood through literature, architecture and art. Spatial representations in visual art, fiction movies and books have contributed to the understanding of space as physical phenomenon. Our perception of space and the relations between what we see and what there is has also been formed by ground-breaking artistic work, such as Picasso's cubism or Magritte's surrealism. Architects have developed theories and skills how to analyse and create physical spaces for human life. The dimension, organization and shape of physical spaces are created in relation to certain needs and certain contexts. Different human needs and human activities require different spatial structures, and these structures are shaped by technological, topological, economic, environmental, social and other conditions. As explained by Yi-Fu Tuan in *Space and Place*, physical space for human life is understood by the notion of place as a phenomenological analysis of space. Space is described in abstract and objective terms while place is concrete and subjective. Basically, for a place to exist, there is need for a space and a human being attached to it (Tuan, 1977). Modernist thinkers and artists such as Rudolf von Laban (concerning performance art) and Le Corbusier (concerning architecture) explain how space is the place that humans take possession of through physical, emotional and intellectual motion (von Laban, 1971) and that physical spaces are defined as machines for humans to live in (Corbusier, 2015), adding to the notion of space as a mental construct.

Space: An entity constituted by the relations between objects and formed by structure. Space exists without observation but appears through human interaction.

Potential Virtual Space

Today we have a completely new world of virtual reality with its spaces. As virtual spaces become more common, developing a conceptualization of virtual space is crucial. New rules and conditions apply for the development of virtual spaces. There are different conditions for dimension, structure and gravity in virtual spaces compared to physical ones. Contemporary knowledge about virtual spaces is based on natural sciences and developed through computer graphics, architecture, art, interaction design, cognitive science, semiotics, hermeneutics, and social science. Virtual space is commonly used as either non-physical space (Ettlinger, 2007; Saunders et al., 2012) or in opposition to real space (Adams, 1997; Malecki, 2017).

The term 'virtual' is loosely defined. With all its widespread use in both popular culture and academic discourse, what does this term actually mean? As a starting point in the framing of 'virtual' in this text, there are some definitions that have to be made. The word 'virtual' could stand for anything that is seemingly unreal or intangible, yet maintains some kind of existence on some other level of reality, in other words, something that exists on a metaphysical level. This can be related to the idea of alternative realities parallel to ours (as found in physics), which remain 'virtual', until they 'actualise'. The view (as found in fiction and poetry) is that the world in which we live might be nothing more than a result of our imagination, and thus what we call 'reality' is virtual as well. The meaning of 'virtual' as something unreal or imaginary is however not used in this thesis. Other uses of the word 'virtual' may have a somewhat metaphysical sense as well. For example, virtual can be used to describe how objects and spaces are imagined through books, music, or other media. This notion of 'virtual space' as a space that is envisioned or visualized internally is not used here, but rather referred to as cognitive space or mental space (Fauconnier, 1994). In quite a similar way, virtual is commonly used to describe our experiences when we browse the Internet or as the third space between two people communicating over distances. In all these cases there seems to be some other dimension in which the contents of these experiences exist – beyond the vibrations in the air, the printed letters on the paper, or the electric signals running through computers – and we need a name for it. So, the word 'virtual', with its inherent ambiguity, often satisfies us as a replacement for a wide range of different things going on. In this thesis 'virtual space' will not be a matter of imagination but rather perception, interpretation and experience; a perceivable and digital non-physical space. A written text is therefore not a virtual space in this sense, because the reader would have to create a mental picture fundamentally different from the pattern of black and white on the book page.

Image Space and Digital Space

For the framing of the term 'virtual space' in this text I will highlight the concepts *image space* and *digital space*. The concept of image space is later discussed for its capacity to describe a space that is not physical, and yet not imaginary. Image space is the abstract space that is accessed through and in images, the overall space of all pictorial media. In this text I make a distinction between (mutually overlapping, but still distinct) spaces: physical space, virtual space, image space, and digital space. The focus on digital space is motivated by a media perspective, where the means of production and modes of interaction are forming both the experience and the structure of the space. Present day communication of knowledge is done via media – journals, online, etc. and thus this digital space of knowledge communication plays a role in creating, communicating and adopting knowledge. The notion of image space is related to human knowledge such as found in art, art history, visual culture, while digital space relates to natural sciences such as computer science, computer graphics, systems and simulations. The intersection of image space and digital space is used to explain the use of virtual space (Fig. 10). This model is an explanation of virtual space as a *latourian hybrid* that has emerged from both culture (art) and nature (science) (Latour, 1993).

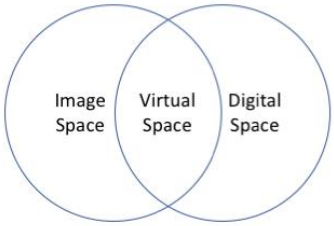


Figure 10. Virtual space as the intersection of image space and digital space

Digital space is constructed from digital information, that is in the context of this thesis discrete information generated by computer or other electronic technology (other examples of digital systems such as the abacus or Morse code are not included here). This data cannot be experienced without representation and mediation. Digital information is represented as digital images and sounds and then mediated through physical screens and speakers to take place in physical space. In this text I focus mainly on visual representation and perception, even though the auditory, haptic and olfactory senses also play important roles in the multimodal perception of space. A digital space does not have to be a concrete representation in the form of a three-dimensional environment, such as a 3D computer game or an architectural model. There are other digital spaces that are formed by for example social interaction, simulation, gaming, or working. However, these digital spaces are only marginally discussed as part of the scope of this thesis since they are not visually perceived as virtual spaces.

Virtual Space: The intersection of Image Space and Digital Space

Virtual vs Actual

What does *virtual* mean in relation to *real*? Is not Virtual Reality just another medium or technology and as such a subset of the real world? Is the virtual a simulation of the real or a representation of an imaginary world? Or the both at the same time? Is it the real that stands for something else or is perceived as something else? The distinction of real and virtual, reality versus virtuality, is an idea that has been investigated and represented over thousands of years, one of the most fundamental being Plato's cave. Peirce defines virtual as "something that is 'as if' it were real" (Liszka, 1996). Virtuality as a philosophical concept in Deleuze builds on Proust's idea of a memory as "real but not actual, ideal but not abstract", developed in the following formulation:

> *"The virtual is opposed not to the real but to the actual. The virtual is fully real in so far as it is virtual. Exactly what Proust said of states of resonance must be said of the virtual: 'Real without being actual, ideal without being abstract'; and symbolic without being fictional."* (Deleuze, 1994)

The virtual is a potentiality that becomes fulfilled in the actual. Hence, it is not material but still real. If we search the answer to the question of virtual vs. real in cognitive science, "the difference between real (actual) and virtual is not as sharp as one might believe" (Dodig-Crnkovic, 2013). Already Minsky in his *Society of Mind* reminds us that even our everyday experiences are not direct and they are not even happening in "real time" (Minsky, 1986). There is always a time delay between the event in the world and our perception of that event, that relies on memory. When observing a scene in "real time" we actually observe only a small part of the scene which is expected to be changing, while the majority of the scene is retrieved from the memory.

When we observe virtual reality, it can happen nowadays that we cannot tell if it is the scene recorded in the real world or a synthetic computer-generated scene. The difference would be the amount of intermediate "intervention" on the information that we perceive. The

degree of intervention can vary – from small changes in photographs to completely de novo generated scenes. However, it is also possible to use recorded scenes and manipulate the content and mutual relations between the parts and the whole. Virtual reality today also includes Augmented Reality (AR) and Mixed Reality (MR), real-world experience augmented by, or merged with, computer-generated inputs.

Virtual space is potential, in opposition to actual physical space, and not in opposition to real.

Physical-Virtual Space

In the beginning, computer technology was not integrated in our physical environment. With the emergence of digital media in the 1980-90's an explosion of development has led to a completely different situation. Concepts from information technology, such as the Internet and computer graphics, are closely related to television, film, and radio. In entertainment areas, like computer games, the two worlds are completely unified. Today there are no important distinctions between digital media and computer technology. More and more physical objects and spaces become digital, computers are becoming ubiquitous, embedded in our everyday objects and environments and embodied in the way we experience them in our everyday life. In human-computer interaction the concept of *embodied interaction* is a way to resolve this physical-digital divide (Dourish, 2001; Ehn & Linde, 2004). The concepts of 'physical space' and 'digital space' have been developed further into the *Four Space Model*, including also 'interaction space' and 'social space' (E. Eriksson, 2011). In our everyday life, in our homes and workplaces, we are not always present only in a physical environment. We also experience virtual environments, mediated through different devices. In certain situations, both professional and otherwise, the relations between physical and virtual spaces become essential for the experience and understanding of the spaces.

Using Deleuze's terminology, the virtual is a surface effect produced by actual causal interactions at the material (physical) level. When one uses a computer, the screen displays an image that depends on physical interactions happening between the actor (user) and the computer (at the level of hardware). The virtual space is nowhere in actuality of the outside world but is nonetheless real and can be interacted with as it is present in our cognition. Simultaneously, the actor is present in a physical space, where the screen works as a window into the virtual world. An actor who interacts with both a physical and a virtual space simultaneously, can be said to be present in a physical-virtual space.

In order to investigate the relations between physical and virtual space, addressing RQ1 on different levels, I focus on the *experience of space* in the phenomenological sense and the *structure of space* in the architectural sense. In the holistic approach presented here, virtual space is the intersection between image space and digital space. Virtual space is seen as separate from physical space in an architectural (structural) sense, but the two worlds co-exist in an interdependent relation. An actor/user/observer can experience presence in both physical and virtual space simultaneously, through an interaction space that involves both physical and virtual space, meaning that this actor interacts in physical-virtual space through an embodied interaction (Fig. 11).

Interaction Space: The intersection of Virtual Space and Physical Space

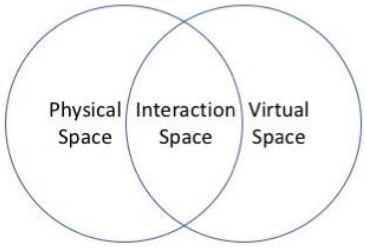


Figure 11. Physical-virtual space as the interaction space

Addressing RQ1 on the higher levels of abstraction (III-IV), physical space and virtual space are entities that exist in reality as subsets of the wider entity of space. The co-existence of physical and virtual space makes it possible to experience both physical and virtual space, even simultaneously, creating a unified physical-virtual space in a phenomenological sense (Merleau-Ponty, 1962). From a phenomenological perspective, the level in the hierarchy of physical space and virtual space is equal, so one is not a subset of the other.

The emergence of Augmented Reality (AR) and Mixed Reality (MR) spaces has led to new experiences and possibilities. From a practice-based perspective, addressing RQ1 on abstraction levels I and II (design practice and philosophy of design), we can see that this co-existence of physical and virtual space also creates a challenge for designers, architects, and artists that work with spaces for human interaction and experience. In the domain of interaction design, the physical-digital divide has been resolved with the notion of *embodied interaction* and connected to space through an increased interest in presence (Redström & Hallnäs, 2002).

This integration of virtual objects and spaces in our physical architectural spaces is positive in the sense that new technology creates new possibilities for us as humans to interact with each other and with the environment around us. The basis of the discussion is that the integration of virtual spaces in our everyday life connects people closer to the world. But if we look with criticism at the relationship between humans and new technology, we can see that these virtual artefacts also are strange and unknown to us. We interact with them but we do not know how this really works, who controls the interaction and why the devices show us what they show. The introduction of more and more virtual space in our physical environment creates alienation, in the sense of estrangement from our involvement with, and relationship to, objects and spaces in our everyday life. People of today cannot possibly understand how these advanced systems work, who has produced them and with what purpose.[14] The emergence of digital media through computer technology can be seen as a revolution so that we now are on a different stage than some decades ago. However, this does not mean that we have left our physical world behind us, but that we now are moving towards a world formed by the synthesis of physical and virtual space, a physical-virtual space.

Touching the Virtual

More and more physical objects are replaced by virtual artefacts, such as calendars, books, and photographs. The same goes for physical spaces that become virtual, such as shops, conference rooms and art galleries. For many common everyday objects and spaces of today, the user cannot even determine what is virtual and what is physical. A car or a dishwasher is no longer

[14] In the original Marxist use of the concept of alienation the focus is on who owns the means of production, but the term alienation is still relevant when we look at the relationship between people and technology in a broader sense.

only physical, and a Wii computer game is not only virtual. The integration of more and more virtual objects and spaces in our everyday life means that we have lost physical touch of part of our reality, but also the opposite, that touch as the tactile sense for interaction has become more important. Different physical gestures are also common in the interaction with virtual objects and spaces.

Intuitively, touch is the sense that can separate the real from the virtual. If seeing is only a vision and hearing is only a voice, then touch is contact with reality. Manipulation of virtual images and sound recordings has made us unsecure and suspicious of information that is based on seeing and hearing, such as 'deep fake'. We need to touch something to believe it, have it hands-on. A mirage can only be revealed by reaching out, trying to touch it, and it is the sense of touch that discloses a glass wall. But can we really trust touch as truth? Of course not. It is as easy to trick our skin as our eyes or ears. Also, in the interaction with virtual artefacts a whole set of physical gestures and touch modes have emerged as part of the interaction language. Users slide their fingers, wave and nod to interact. These modes of interaction are virtual in the sense that they simulate a real-life physical interaction.

The Physical-Virtual Hierarchy

This thesis wants to challenge the conventional 'master and slave' relationship between physical and virtual space, where virtual space often is seen as only a replica of actual physical space. Actually, this seems not to be the case. For example, we do not only use VR as a simulation to practice what can be done in 'reality'. In paper I, we show that learning to solve the Rubik's cube puzzle transfers better from physical to virtual than the opposite. In many cases, the virtual-physical hierarchy shows to be arbitrary so that virtual space can be seen as an interface to physical space and vice versa. In our physical-virtual world there are many cases of this equal status of space. For example, a furniture store could be seen as both a virtual and a physical world. For someone who is used to visit the physical warehouse and then experiences the furniture store web site for the first time, the web site becomes a representation of the physical structure of aisles and shelves, but for someone who has only interacted with the furniture store online and experiences the physical store for the first time, the structure of the physical space is understood as a representation of the virtual. The physical architecture becomes an interactive interface to serve a certain purpose. Also, the transfer of meaning is mutual, so that experience from one space affects experience in another. Seeing creation of meaning as an act of communication, it is in the interplay between reality and virtuality that the development of concepts in our physical-virtual world is made.

Physical and virtual space are mutually interdependent, and one is not only serving the other.

"Being There":

Seeing Virtual Space Through Perception Mediated by Technology

In order to explore RQ1, a deeper understanding of virtual space is needed. Virtual space can best be studied when created by Virtual Reality (VR), an invention, engineered by advanced computer technology. VR technology presents both a "tool" and a "world". VR is a computer medium used as a tool to convey a message to a user, just like any other medium. At the same time, as a medium, VR can be so perceptually persuasive and interactive that the user/actor can experience *presence in* the virtual environment which thus plays a role of a world. Using Virtual

Reality as a way of exploring what a virtual space is, and what it can be, goes back to the pioneers of VR (Sutherland, 1965). The technical definitions were stipulated in the 1980's by researchers in the field of computer science and neuroscience (Ellis, 1991). An important conclusion of these views was made in *The Metaphysics of Virtual Reality* (Heim, 1994) that analysed virtual reality into seven different concepts: simulation, interaction, artificiality, immersion, telepresence, full-body immersion, and network communication.

A typical technical description of Virtual Reality reads *Interactive Visual Real-Time Computer Simulation*. Hence, in order to be able to claim an environment 'virtual' we need to fulfil these five conditions (interactive, visual, real-time, computer-based, simulation). There are numerous variations on this definition, such as in *The American Heritage Science Dictionary* "A computer simulation of a real or imaginary world or scenario, in which a user may interact with simulated objects or living things in real time." (*The American Heritage Science Dictionary*, 2019). Here *Interactive* means an active interplay between user and virtual space or between user and user in the virtual space, hence open for intervention from the user. The term *Visual* relates to that vision was the first sense to be used in VR, while the other senses were regarded more as complementary modes of virtualization (Ellis, 1994). In contemporary virtual spaces we see more of multimodal interaction, using aural and haptic interfaces, even though visual simulation is almost without exception in focus. The technical term *Real-Time* sets a limit for what is considered to be immediate response.

Virtual space is changing the way we live our daily lives, both as a society and as individuals. We can be present in virtual worlds and have access to virtual institutions and workplaces. Through the technology of Virtual Reality, Augmented Reality and Mixed Reality we get new experiences and gain new knowledge. New hybrid physical-virtual spaces emerge with new possibilities for interaction. The majority of research and development in Virtual Reality has been to use it as a way to simulate physical reality (Slater, 2009). Yet VR is a medium that has the potential to go far beyond anything that has been experienced before in terms of transcending the bounds of physical reality, through transforming your sense of place, and through non-invasive alterations of the sense of our own body. In other words, virtual reality has rarely been seen as a medium in its own right, as something that can create new forms of experience, but rather as a means of simulating existing experience (A. Axelsson et al., 2001; Brooks, 1999). VR needs to be handled as something with its own unique conventions and possibilities that provide a medium where people respond with their whole bodies, treating what they perceive as real.

Virtual spaces give new experiences. In a virtual space, we could for example see temperature and air flow in a room, listen to molecules, walk around in buildings that are about to be built, alter the chain of events in a historical scene, or fly through galaxies experiencing the birth of stars. Through Virtual Reality all these things can be communicated perceptually and not by suggestion, dreams or hypnosis. Concerns about Virtual Reality and other digital spaces are raised, that these offer a "low-resolution" life (Taylor, 2011), which refers to the low granularity or low media richness of multimodal sensory input in comparison with 'real life'. Virtual spaces are here seen as 'almost real'. These concerns are valid for situations where certain aspects of realism or face-to-face communication are lost, but on the other hand we must realise that Virtual Reality also makes new experiences possible. We can be tele-present with others over long distances and augment our senses with new representations and layers. Virtual spaces are hence also 'more than real'.

Understanding virtual space through cognition, we need to focus on the user's experience of immersion and the concept of *presence*, the sense of 'being there'. Studies have shown that the degree of immersion in a virtual space has a positive relation to the degrees of user performance, communication and collaboration in VR applications (A. Axelsson et al., 2001; Slater et al., 2000), meaning there is an objective to take the technology further, hence 'more virtual'. In this area of experience-oriented definitions, I see five factors connected to presence

that are important to present here. These factors are *Perception, Transparency, Transportation, Attention* and *Social factors*. Here *Perception* means the sum of all sensory input that together give the user a sense of being in a space, other than the physical space that the user is physically present in. A higher quality of sensory input is regarded to lead to a higher degree of presence (Slater, 2009). Image, sound and touch can today be virtualized to an almost life-like level, so that the user will have trouble telling the physical from the virtual, in a mere sense of perception. However, the *Transparency* of the medium is not always as high as one strives for in order to keep a high level of immersion. Computer screens can have poor resolution, there might be cables that users get tangled in, there can be delays in the communication or low frame rate. Apart from technical problems there can be disturbing real-world noise or light, or the user can get nauseous. These are all examples of presence-breaking factors due to low transparency.[15] *Transportation* is a factor that actually reaches the core of Virtual Reality. It has to do with the sense of being in another place, to move away from or beyond physical space and 'travel' to a virtual space. The comparison with cyberspace[16] is not far away here, in an everyday meaning. When we use the Internet, we use metaphors such as 'visiting' a website and 'surfing' the Internet, even though we just download data from a server to our own computer. It is the same sort of agreement that a user can make with a virtual space, if the environment uses those sets of metaphors that encourage traveling. However, these three presence factors mentioned above could all be over-ruled by the *Attention* factor. This issue has to do with how interesting and meaningful the environment is for the user. It does not matter if the VR application runs on a giant screen in real-time, completely wireless and immediate in response, if the user is not interested or if it does not make sense. And the other way around, if the user is completely focused on or is fascinated by the content in virtual space, a lot of perception and transparency failures will be forgiven. The coherence of agreements and experiences creates the plausibility of the virtual space (Slater, 2009). We all know how we start noticing what the chair feels like in a movie theatre if the film is boring, or how we can forget thirst or hunger when we get lost in an exciting book. I have on many occasions seen people so excited about a virtual world that they laugh out loud, cry, jump back or even fall over, from just a crude set of polygons shown in the right way at the right time. *Social factors* are also very important for the degree of presence, due to the obvious reason that we are social beings and as such we are affected by other peoples' interactions. If there are other virtual subjects (avatars) users can meet and interact with, the user will feel more present in the virtual space, in the sense of "being there together" (Schroeder, 2010; Wideström et al., 2000).

A key aspect of presence in virtual space is the difference between watching and acting. One of the fundamental concepts of VR as realistic simulation of physical environments, is that the user is understood as a viewer that gets access to the virtual world through a camera (point-of-view) in the virtual model. Here presence is measured through the degree of immersion in the virtual environment by realism, in framerate and screen resolution. This immersion creates a "place illusion" that gives the user presence, in the sense of "being there" (Slater, 2009). The presence can be broken by inconsistencies in behaviours and actions. Therefore, a high degree of presence also requires that the "plausibility illusion" is fulfilled. This does not mean that the virtual space has to be realistic, but rather coherent in relation to the agreements that are made between actor and space. Virtual space becomes a place for human life through the cognitive processes of navigation and identification.

Virtual Reality: The interface for enabling presence in virtual space

[15] Key factors for presence-breaking is presented in detail in *Temporal and Spatial Variations in Presence: Qualitative Analysis of Interviews from an Experiment on Breaks in Presence* (Garau et al., 2008)

[16] Cyberspace, a widespread interconnected digital space, as made popular by William Gibson's famous novel *Neuromancer* (Gibson, 1984).

Embodied Virtuality

For further investigation of RQ1, the relations between virtual space and our physical body is vital. Virtual Reality is often seen as a medium where the human body is detached, that an actor in a virtual space is disembodied. One reason for this is that VR has a background in the ideas about cyberspace, which is explored by the mind rather than the body. Another reason is the conceptual and technical background of VR in its early military and scientific use, where the actor in a virtual space is regarded primarily as a camera with a point-of-view and secondly as a hand with some type of interaction device. The actor is actually somewhere else, outside the virtual space. It can of course be argued that, no matter how transparent the interface is, the user is always in front of a screen or looking into the virtual space, he or she is not actually "there". But what is actually the difference? Isn't it true that we see, hear and interact with a virtual world using our bodies and senses just as we do in the physical world? We are as humans trapped in our own bodies; we can never really be disembodied (Wideström & Muchin, 2000). We can always in our dreams and fantasies leave our physical reality, but when it comes to perception of an outside world, there is no fundamental difference between reality and virtuality.

Phenomenology, the philosophical study of experience and consciousness, constitutes the conceptual base for investigating the relations between physical body and virtual space. What Husserl says about our *lebenswelt*[17] applies well to how we experience the virtual as real and vice versa. Husserl's idea of lebenswelt shows how everyone lives primarily in a subjective world of cognitive space, rather than in directly in a shared physical one (*Stanford Encyclopedia of Philosophy*, 2016). All spaces around us can be regarded as virtual, since we are unable to reach outside of ourselves, and all self-experience can be regarded as real, since that is the only knowledge that exists. In that context, the question of reality and virtuality is completely detached from an analysis of the world around us. However, these phenomenological concepts do not oppose to VR as an embodied medium. As such philosopher of phenomenology, Merleau-Ponty uses the concept of *corps vivant*[18] to describe how perception is integrated with both the physical and mental aspects of the human body, so that body and space becomes one (Merleau-Ponty, 1962).

In virtual space, abstract things need to be represented as concrete, hence make them perceivable (visible, hearable, touchable etc.) in order for them to take place in the world. We can call this process 'virtual concretism' (Fig. 12).

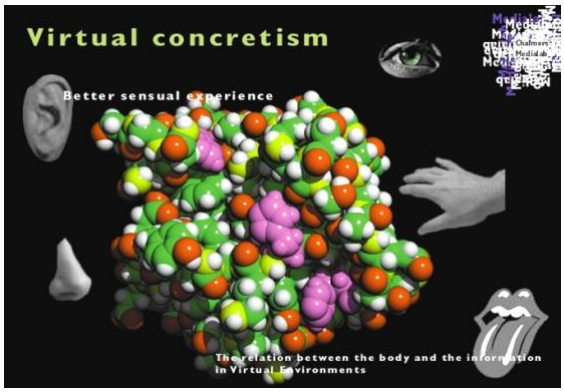


Figure 12. Virtual concretism, illustrating the human senses in virtual space (Andersson, Flygt, Chalmers Medialab, 1999)

[17] Lebenswelt (German for 'lifeworld'), the self-evident world to be experienced. Edmund Husserl (1931) *Cartesianische Meditationen und Pariser Vorträge*.

[18] Corps vivant (French for 'living body'), the integration of 'corps propre' (French for 'own body') with both mental and physical space. *Phenomenology of Perception* (Merleau-Ponty, 1962)

In the projects I have been working on, I have found it very interesting to keep in mind that interacting with VR is an embodied experience. What does it mean to, for example, fly around inside molecule? Does it feel like your body is actually scaled down to the size of a carbon atom or does the molecular structure seem like a world of large-scale spheres and sticks in a gigantic aquarium? And how does it work if there is no gravity in the virtual world when your body is still affected by the gravity in the physical world? The answer is to a great extent: it depends. My conclusion from working with various VR projects is that a person's bodily experiences from a VE depend mainly on two factors; firstly the expectations of the actor and the agreements that the actor makes in/with the virtual world, and secondly the spatial context of the VE. As a presenter of the VE I can affect the person entering the VE by just saying "you will now be scaled down to the size of an atom" and that statement will then create a frame for what he or she will experience. The spatial context is also crucial to many of the agreements made. If the virtual molecule is put inside a 3D-model of a biochemistry lab the experience of the application is completely different from when the molecule is placed in for example an "outer space" setting with stars and galaxies. This process works in the same way as when a person enters a building or meets a group of people in the physical world. VR is sometimes compared to a mental world or even a dream where everything is possible and abstract, but to me VR is the quite opposite; a concrete representation of knowledge, feelings and ideas using signs and codes that can be perceived by the human senses. There is nothing unreal about Virtual Reality.

I believe that the most straight-forward way to discuss VR as an embodied medium is to analyze the relationship between human body and virtual space. In the period of 1999-2001 I worked with a series of projects in collaboration with the Academy of Music and Drama at Göteborg University. We based our studies on previous work by Laban[19] and Le Corbusier[20] made in the 1940's that showed the human body in a direct relation to physical space, and how that connection works in theatre and dance actions, and in architecture. Laban states that:

"Space is the place that humans take possession of through physical, emotional and intellectual motion. The size and shape of the space is determined by outer limitations. The void between the limitations defines the possibilities for the individual to expand its own space relative to the outer limitations. When humans enter a space, the connection between humans, space and objects creates an expectation of muscular, intellectual and emotional preparation. This constitutes to the foundation of the agreement between humans and space called the extrovert space. Into this space humans carry their own physical space called the introvert space." (von Laban, 1971 p.30)

Le Corbusier said that buildings are "machines to live in", but that statement does not imply that spaces to live in should be art-less, soul-less or just optimised for robots. It means that we need to understand and accept modern technology as our natural space, with the human mind and body as the ruling condition and benchmark (Corbusier, 1954, transl 1967). It is the architect's role to interpret this relationship in an artistic and creative way, in order to create architectural space.

With the history of VR from military and other simulations, this spatial medium uses a person's POV as the physical centre of the human body, while previous theories and models of the relationship between body and space have shown that it is rather the pelvis that is the physical centre of the human body (Fig. 13-14). Making these models concrete in VR, we put a magnetic tracking device on the back of the VR user's belt and assigned that to the directions of forward, backwards, up, down, left and right in the VE, and compared that with using the

[19] Rudolph von Laban's 1948 publication of "Kinetographie Laban" is a dance notation system that came to be called Labanotation and is still used as one of the primary movement notation systems in dance

[20] Le Corbusier's *Modulor* from 1954 is a system for the scale of architectural proportion, where he used the proportions of the human body to improve the appearance and function of architecture

person's glasses or the person's hand as the reference point as it is normally done. Using the pelvis as the physical centre of the VE led to a completely different understanding of the environments and how the user could interact with the VE, both mentally and physically, as described in paper II (Fig. 15).

Our study of traditional eye- or hand-centered navigation in VE's showed two important problems to solve; the problem of orientation and the problem of gravity. Firstly, there was no connection between the user's physical centre and the concepts of navigation/orientation. Therefore, the experience from the application was like driving an invisible vehicle simulator. Secondly, realistic or concrete VE's give the user an expectation of gravity. When the experience of gravity is missing, the agreement between human body and space doesn't work, and the user gets confused about the concepts. We found that connecting the physical centre to the concepts of navigation/orientation was the most important issue, but it was also necessary to separate the visual/perspective centre from the spatial/physical centre. It is quite natural that the eyes (POV) should work as a visual centre, since people see with their eyes. It should be just as natural to use the pelvis as the physical centre, since that is where the direction of the human body in relation to space is centered. The improved sense of balance using this model for interaction between the human body and virtual space was also a major factor to lessen VR nausea.

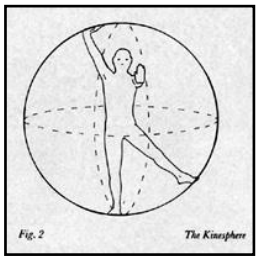


Figure 13. The Kinesphere (Laban, 1948)

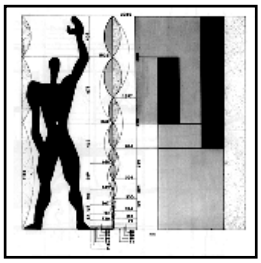


Figure 14. Le Modulor (Le Corbusier, 1928)

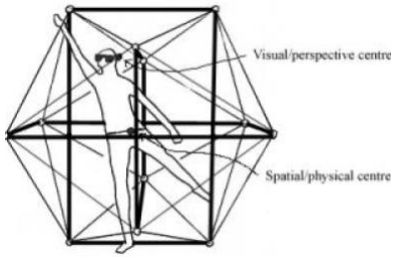


Figure 15. The Virtual Icosahedron, (Wideström, 2000)

The concept of *presence* is vital to the idea of virtual space, as well as the relation between body and space. Presence in virtual space is based on an *agreement* between human body and space that can be seen as the link between expectation and the experience. Looking closer at the concept, presence can be analysed in the aspects of attention, perception, transparency, transportation and social factors. When looking at the interplay between body and space it can be noted that, over time, our experiences of the world form patterns (preferred interpretations) that lead to expectations of coming experiences. We can never remain completely blank in our perception of the world. In that sense, virtual reality is interesting since it is a medium with the capacity to extend our senses, let us move unexpectedly through space and time, and implement different rules for orientation, scale, gravity or interaction. New agreements need to be made. Taking a semiotic perspective, this means that virtual reality must have a different set of signs in order to communicate and handle an alternative way of interaction. The Peircean[21] triads of signs, objects and interpretants are re-defined so that a new semiotic code is established, which leads to new creation of meaning in the interaction between body and space.

[21] The semiotic triad of as described by Charles Peirce, see page 57.

Communication and Collaboration in Virtual Space

An important aspect when exploring RQ1 is also the social dimension of virtual space, where actual people are interacting together in virtual environments (VE's). When looking at communication in VE's, there is a wide spectrum of different contexts regarding computer mediated communication, which includes virtual project rooms, video conferencing, chatrooms etc. What I have worked with in this field are questions about communication and collaboration in VE's, using VR technology and VR interfaces as presented above. The focus of the different projects has been if people can have a sense of "being there together" when they are only meeting in a virtual world, to what extent and with what limitations. As shown in Paper I, people can actually collaborate quite well in a VE, performing a complicated task together. In one of my recent studies *Lectures in Virtual Reality – Is It Worth the Effort?* (T. Eriksson et al., 2020) we use multi-user VR to give a lecture, using VR headsets as an interface to the virtual classroom. I find virtual classrooms very interesting to study in relation to communication and collaboration in virtual space, since they are well established as collaborative spaces and constantly developing in the use of new technology. With the emergence of off-the-shelf Virtual Reality, Augmented Reality, and Mixed Reality systems in the 2000's, new collaborative learning experiences have been made possible and explored (Dalgarno & Lee, 2010; De Freitas et al., 2010). For example, HMD systems have been used for educational purposes, both in classrooms and from home, in order to experience natural science phenomena or travel in time and place (Jolley et al., 2018). In VR, groups of students can experience molecular visualizations and quantum physics in the smallest scale, astronomy in the largest scale, and also make study visits on virtual field trips (Procter, 2012). In relation to my work, paper III shows that the choice of VR system as interface to the environment affects experience, co-presence, and collaboration between users, such that symmetrical VR settings are preferred (Heldal et al., 2005).

Since the 1990's, there has been a flood of studies of collaborative virtual worlds such as Active Worlds[22], Everquest[23] and Second Life[24], showing similarities and differences between physical and virtual communities. Looking at these worlds from a set designer's or an architect's perspective, it is clear that the design of the environments to a great extent is a combination of people's conventions, crude technical conditions, and chance. Even though that might be said about many physical spatial designs as well, there are some interesting remarks that can be made about these collaborative virtual spaces. First of all, it is stunning to see a majority of rather traditional houses that are built by the citizens, residents and world owners[25]. Most houses have four walls, separate floors and a solid roof, even though users tend to fly around as much as they walk, and even though it never rains (Fig. 16). This is very interesting, in relation to RQ1. We seem to use the experiences and mental models from the physical world when we interact and design in virtual spaces, even though the conditions for interaction and creation are completely different.

[22] Active Worlds was released in 1997 as a web-based 3D virtual world. It is used for meeting other people and building virtual objects and buildings. The administrators claim to have accepted hundreds of thousands of citizens to Active Worlds. Millions of tourists have visited Active Worlds and hundreds of million objects have been built.

[23] Everquest is a Massively Multiplayer Online Roleplay Game (MMORPG) released in 1999, a virtual world in the fantasy genre where game players advance by collecting experience points from different quests.

[24] Second Life (SL) is a 3D collaborative world on the internet since 2003, using SL dollars that can be exchanged for real money. Real currency has also been used in for example the Entropia Universe virtual world.

[25] Different worlds use different terminology for their users. Users can also be on different levels with different abilities and rights to build.

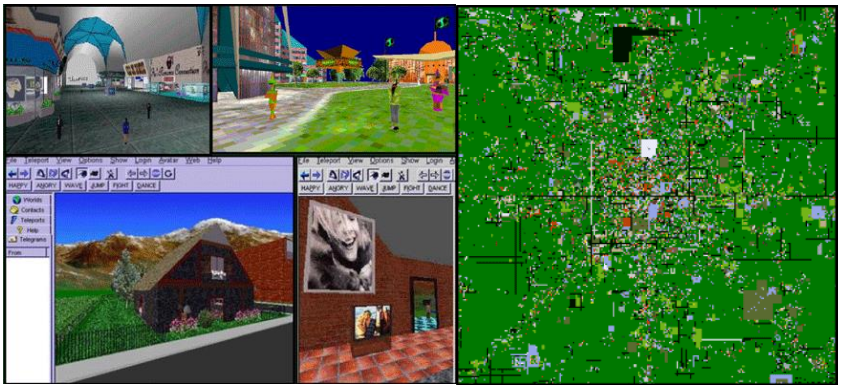


Figure 16. Screenshots from Active Worlds (Active Worlds, 1999)

I have previously described presence, the sense of "being there", as an important concept when analysing VE's. *Co-presence*, thus the sense of "being there together", is a key concept to collaboration and communication in multi-user VE's. For other media, issues similar to co-presence are often discussed using the concepts of social presence, multimodal interaction[26] and media richness[27] (Daft & Lengel, 1986). Multi-user VE's are a rich medium in the sense that they allow people to interact via several senses. Users interact via audio or text combined with a 3-D visual environment, either in an advanced IPT/HMD system or on a more commonly used desktop setting, where the degree of co-presence is not measured in realism. This puts collaborative VE's apart from telephony, video conferencing and other media of communication, and makes collaborative VE's a truly spatial medium.

In the research projects dealing with social issues of VR, Chalmers Medialab collaborated with the Technology and Society research group[28] at Chalmers. To investigate the factors of co-presence, collaboration and communication in shared multi-user VE's we set up different environments using the Chalmers IPT system, HMD's and desktop VR systems. The project that has been most fruitful in terms of research results is the Collaborative Cube Puzzle. As described in paper I and III, the trials were carried out in a collaborative VR setting (Fig. 17). Using one IPT system at Chalmers and one similar system in London, two people could collaborate in a VE on a Rubik's cube-type puzzle solving task. We showed, by comparing this task with the equivalent task carried out in a physical setting face-to-face with cardboard boxes, that such a highly spatial and collaborative task can be done just as effectively in networked VE's as in a physical face-to-face setting, when using high-end VR systems.

[26] Multimodal interaction provides the user with multiple modes of interfacing with a system beyond the traditional keyboard and mouse, as in high-end VR systems.

[27] Media richness was defined in 1986 by Daft and Lengel as "the ability of information to change understanding within a time interval". The idea is that greater social presence of a medium creates a greater immediacy of the communication, because of the greater number of channels.

[28] The Chalmers Technology and Society research group at Chalmers was led by Prof Ralph Schroeder from 1998-2005.

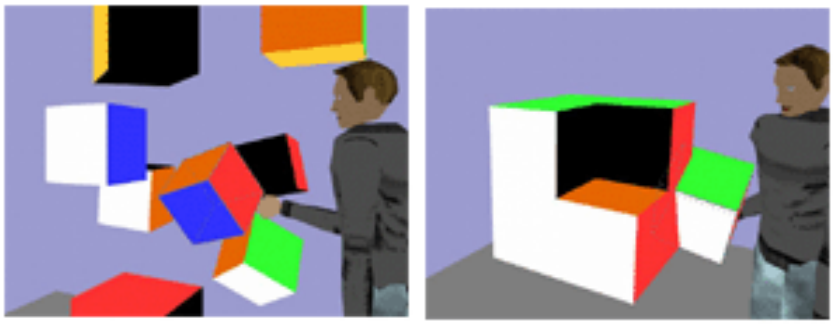


Figure 17. The Collaborative Cube Puzzle (Widestrom, 2000)

The trials also showed that when we used a more low-tech desktop VR system for one user and a high-end IPT system for the other user, the users' performance was very poor in terms of not only collaboration and communication, but also solving the puzzle. This is described more in detail in paper III, arguing that symmetrical settings regarding interfaces to the VE are beneficial both for performance and collaboration. We had persons using the desktop asking the person in the IPT how he or she could move around so easily. "Just bend your knees" was the answer, which was not easy for the person using the desktop to understand. The different concepts that the users had about their different spaces (relations between human body and space) were the reason for this misunderstanding. Today, this spatial issue becomes more and more topical when people are starting to use more and more different types of systems for interacting with VE's. A person in a multi-user VE using for example a desktop VR system could meet another user in the VE that, on his or her side, uses a completely different system, such as a mobile phone or a high-end VR helmet or IPT. Users may actually have completely different levels of media richness, even though they appear and interact together in the same space.

Another interesting aspect of this trial was that it was a comparison between physical and virtual. It would seem like a top-of-the-drawer method in research about VR, but still surprisingly few research projects deal with this comparison. When training simulations are designed for virtual vehicles, space shuttle repairs or complicated chemical processes, we tend to assume that we learn something from the VE and bring that experience to situations in the physical world. But how does that process work? What we actually found in this limited task setting, was that the persons that first did the virtual task and then the physical task did not perform much better in physical that the persons that did the physical task for the first time. However, the reverse seemed to apply, so that the persons that first did the physical task and then the virtual task performed better in virtual than the persons that did the virtual task for the first time. This means that it would give more effect to create a physical environment in order to practice a virtual situation, than the opposite. In order to draw any general conclusions from this result, one would need to make more trials and also test the long-term use of virtual environments. However, this case provides a relevant argument for challenging the 'master and slave' hierarchy between physical and virtual space, as well as one of the main findings in relation to RQ1.

In this area of research, we also investigated a setting where two persons were standing inside the same immersive VR system, interacting with a virtual large-scale molecular structure[29]. The two persons were immersed in the same virtual space, but they could also see each other in physical space at the same time. One person had the hand control and therefore

[29] The molecule was a Cytochrome-C protein amino acid structure with more than 5000 atoms. Visually, it was represented in a standard multi-coloured ball-and stick model. It also had sounds connected to the different amino acids, so that the users could recognise the different parts of the molecule by listening.

became the pilot, while the other person became a passenger. They were supposed to solve a task together, identifying certain atoms and structures. In their interview answers, it was clear that the pilot felt more present in the VE than the passenger (A.-S. Axelsson et al., 1999). This means that a user's spatial experience of a VE depends on the level of interaction and involvement. In other words, doing creates a stronger sense of presence than watching.

Presence in Virtual vs Physical Space

Concluding the relations explored in RQ1, there are clearly spatial concepts in virtual reality that are different from the spatial concepts of the physical world. When we talk about presence in the physical world, we equal that to engagement or use present in contrast to absent-minded. In virtual space the concept of presence is more concrete, it refers to whether a person can perceive space to a degree so that he or she feels like "being there" rather than in the physical space that the person is actually in. When a person enters a virtual space, he or she knows that it is not "for real"; the user needs to engage in the VE voluntarily in order to feel present. In everyday life in the physical world, we do not need to make such agreements consciously. Also, physical presence is regarded as something positive in the physical world and as something negative in the virtual world. To be reminded of the physical space, when immersed in virtual space, is presence-breaking.

However, there seems to be more similarities than differences in how we perceive physical versus virtual space. There are a number of factors and phenomena that work in the same way in physical and virtual worlds, such as human sensory input. There is no difference between the perception of image, sound and smell in a physical versus a virtual environment. Also, communication and collaboration in virtual environments seem to work in patterns that we know from face-to-face situations, regarding group dynamics, social control etc. In terms of computer-mediated communication, VR is a spatial medium that can be seen as a complement to the range of communication tools that have existed for a longer period of time. VR is also a spatial art form that has its own properties just like sculpture, theatre or music, but the fundamental artistic questions and concepts are the same as in other forms of expression. Set design might be the art form that is closest to VR, since they both have an ambition to create a spatial illusion over time, with an audience that need to "want to believe" in order to be present in the artwork or play. This relation between virtual space and stage design will be explored further in this thesis.

I have also given examples of concepts that are used or interpreted in different ways in physical and virtual spaces but are essentially the same, so that they reflect on each other and explain each other and give new meaning. The two main concepts here are *body* and *agreement*. I believe that the relation between human body and space holds a key to the understanding of how meaning is created and represented in both virtual and physical spaces. On one level we have to accept that the human body and mind is a machine and that virtual space, just like architectural space, is a machine to live in. This means that when we create extrovert spaces in the form of VE's we always have to deal with the introvert spaces that they interact with. A virtual space without interaction with both human body and mind is not virtual reality, it is detached from reality. It is the agreement that the human body and mind make with the virtual space that structures this dynamic relation of interaction and experience.

In this text there are a number of examples of how our experiences from the physical world form the way we interpret virtual or mediated worlds. It is no surprise that when we experience a virtual space, we structure the information so that we can understand it, based on what we know from and how we see the physical world spatially. What I also investigate in my work is the opposite line of experience and agreement, that our understanding of virtual spaces also form the way that we interpret the physical world.

Observer/User/Viewer/Actor and the Role of the Virtual

Exploring RQ1 on the higher levels of abstraction, I apply a philosophical approach to virtual space. Here, it is necessary to not only investigate space on a structural level, but also put the human in the center. I argue that a deeper understanding of the relations between physical and virtual space emanates from human interaction and perception. In the current renaissance of multidisciplinarity, we want to understand the relation between the observer and the world. In this context, the works on phenomenology by Husserl and Heidegger have found new interest. Husserl's phenomenological reduction (the suspension of judgment about the natural world and focus on subjective experience) and Heidegger's concept of Dasein or "being-there"[30] are now used to create new frameworks and extended theories for the relations between the observer and the world, philosophy and natural science, between culture and nature. The human is not only an observer, but importantly also an actor in relation to the world.

Brier's transdisciplinary theory of *Cybersemiotics* (Brier, 2013), presents an attempt to meet this challenge of connecting the observer with the outside world. By combining the 19th century Peircean semiotics, with contemporary theories of phenomenology and cognition, Brier constructs a non-reductionist framework for the integration of natural sciences with first-person experiences (cognition) and social interactions (culture). Cybersemiotics sets semiotic cognition in the centre for the understanding of reality, connecting to the four aspects; surrounding physical nature, biological corporality, subjective experience, and our social world. Through Brier's distinct analysis it becomes clear that humanities and sciences enrich each other and that this mutual dependence create not only a wider perspective but also a deeper understanding.

Rössler's Endo-physics presents philosophical extension and interpretation of the natural sciences (Rössler, 1998) that is important to the understanding of virtual space. Much as Rössler proposed in endo-physics, reality as the interface between outside (exo) and inside (endo) worlds, Virtual Spaces are understood from within the spaces, through their interfaces. Rössler states that "The observer does not see the world as it is, but only the 'interface' between himself and the world" (Rössler, 1994). Observer and interface are therefore just as central issues in endo-physics as in conceptualization of virtual space. The observer is represented in the virtual space as a camera or a viewpoint that changes the space. From the exo-perspective, virtual spaces can be measured in bytes, polygons or pixels, while it is only from the endo-perspective that the space can be subjectively experienced. The human being is therefore part of this virtual universe, and the world is the interface between the observer and the rest of the world, using Rössler's terminology. The difference between virtual space and the actual world that Rössler discusses is that we as creators of virtual space have access to the interface, and design the interface, meaning that we can actually step outside the virtual world into the remaining (actual/physical) world. Still, the observed reality from within relies on subjectivity as the observer inevitably distorts the world or *actively* perceives and constructs the world locally. Virtual space has the potential to work as model worlds that simulate exo-models of endo-systems.

All of these post-modern theories strive to find meaningful analysis of complex systems, without reducing these systems to mere physics and/or information. They show that one can include first-person experience and thought as well as social communication in natural science without making it arbitrary or random. Virtual space is a true *hybrid* in Latour's meaning, with its emergence from nature and culture: "Nature and culture shape each other, producing hybrids"(Latour, 1993).

[30] *Dasein*, German for "being there" or "presence", human existence in the world, as described in *Being and Time* (Heidegger, 1962).

As I describe in paper VI, *The Transdisciplinary Nature of Virtual Space*, this first-person perspective in natural philosophy connects to the human-centred understanding of virtual space (Wideström, 2019). These connections are different in different domains, which contribute to a diverse understanding of virtual space. From a semiotic perspective, new connections can be made between the codes of the overlapping domains that inform the knowledge of virtual space. The relations between natural philosophy and virtual space extend the semiosis (sign process) in these domains. When natural science meets philosophy and arts in this context, new knowledge is created. This production of new knowledge does not only happen by random connections, but also from intentional, designed efforts by the communities (both theorists and practitioners) from the different domains.

The human can take different roles in virtual space; the *observer* that registers the world, the *user* that create meaning through interactions, the *actor* that uses the space as a stage, and the *viewer* that relates to the space as a form of visual arts. When the *observer* discussed by Rössler in terms of interface with endo- and exo-reality, is the observer in virtual space, its interactions are often focused on visual aspect (optics). The observer in a three-dimensional virtual space is represented as a camera that changes the projected view from the observer's perspective by the rules of optics. In analogy, sound and haptic feedback can adapt to the observer's location in the virtual space. In interaction design (the practice and theory of designing interactive digital products, environments and systems) the human is understood as the *user*. From this user-centred perspective, the focus is on human-computer interaction and behaviours. This means that interaction design synthesises digital space, physical space, interaction space and social space through an embodied interaction between human and space (E. Eriksson, 2011). In performance arts the relations between human and space is articulated by the triangular relations between actor, stage and spectator (Ljungar-Chapelon, 2008). The *actor* makes use of the stage in relation to a narrative with the spectator as audience. This notion of human and space contributes to the understanding of virtual space through the 'stage' metaphor. This conceptual metaphor puts the actor in the center and leads to other connotations such as 'behind the stage' for the backend of virtual space. In visual arts the human is seen as a *viewer* and/or creator that relates to the work of art in different ways. This view of the creating and observing human puts virtual space in an artistic discourse, leading to the understanding of virtual space as image.

Image Space, Visual Arts and Aesthetics

A further exploration of RQ1 on the higher levels of abstraction leads to questions about virtual space as an artistic gestalt, where aesthetic aspects become important. Seeing virtual space as a form of visual arts is relevant for understanding the relations between physical and virtual space. Here, I start with an investigation of image space as a way to explain virtual space.

When we look at a pictorial image, what do we see? Or more importantly, in relation to space, *where* is that thing we see? Whenever we look at a pictorial image of any kind, our eyes may be looking at a physical object in the physical world, a canvas or a screen, but what we are seeing through this object is not part of the physical world. For example, when we look at the photograph of a person, our eyes are staring at the computer screen and its coloured pixels or at ink dots on a paper, which are part of the physical world. And yet, the person that we are seeing is not in the physical world. Even though there might be a person just like that somewhere, the particular person in front of us at this moment does not occupy physical space in the sense that it is hovering directly behind the computer screen. So, where is it then? The notion of 'image space' suggests that what we see in a pictorial image is located in another space that is neither physical nor imaginary.

Using the pictures below as examples, it is understood that images can represent spaces that exist or do not exist in the physical world while the image itself belongs to physical space and what it represents to image space. Durer's picture to the left (Fig. 18) shows how a physical object can be represented on an image plane using physical threads as connections between the viewpoint and the object. In Escher's picture to the right (Fig. 19), there is no physical object or space that is represented in the image. Both images are also representations of ideas and work as interfaces to those ideas.

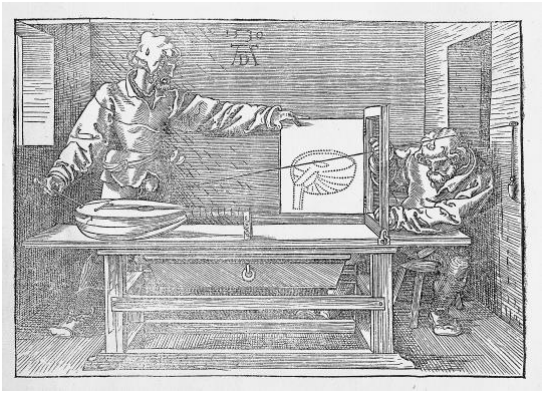


Figure 18. Institutiones Geometricae (Dürer, 1532)

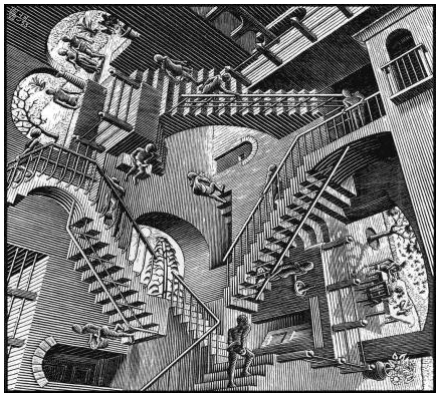


Figure 19. Relativity (Escher, 1953)

Image space is not just the space of a particular picture, but rather the overall space of all pictures, and of all pictorial media. This is stated in analogy with physical space that is the overall space of all physical places. Image space is the abstract space that is accessed through and in images. Structurally, images work as interfaces to image space where the semiotic code forms the language of creating and reading images. Meaning is produced in a communicative process that involves context, space, representation, and interpretation. Consequently, digital space is the overall space of all spaces created by digital media.

The idea that this 'image space' is actually what should be considered as a conclusive definition of 'virtual space' has been put forward by Ettlinger in *The Virtual Space Theory* (Ettlinger, 2007). This theory is an ambitious attempt to define virtual space as something detached from both metaphysical connotations and computer technology. However, this means that this theory is also detached from media theory and does not recognise the fundamental changes of the relations between physical and image space in the revolution of

digital media. The image space as founding concept is also brought up by Oliver Grau in *Virtual Art – From Illusion to Immersion* (Grau, 2003). In this book, Grau shows how virtual art fits into the art history of illusion and immersion. Although many people view virtuality as a totally new phenomenon, it has its foundations in a history of immersive images. Examples of illusionary visual space can be traced many centuries back. Grau describes the metamorphosis of the concepts of the image and relates those concepts to interactive art, interface design, agents, telepresence, and image evolution. He reflects art history in media theory, showing the phenomenon of virtuality beyond the hype. Grau gives examples of how each period in history used the technical means available to produce maximum illusion. In that sense, virtual reality is just a novel interface to 'image space', not a fundamentally new phenomenon of its own.

Seeing the image as an interface to image space emphasizes the importance of understanding the functions of the image: its dimensions, properties, and its function as a sign. An important function of the image is visualization, in the sense of representing something externally in visual form. That 'something' might be concrete information or abstract ideas, real or imaginary, but its representation in visual terms is physical and concrete. Visualization is the act of communicating this something using the image as medium. This communication does not follow any given rules or simple recipe but is rather open to a continuous negotiation and development of new concepts. In the evolution of images, from the first cave paintings to the high-resolution, interactive visualizations of today, the development has not only been technological but of course also conceptual. Contemporary image media have not only created new ways of accessing image space, but they have also transformed the space. New ways of creating and interacting with images have made new spaces possible. The image is not just an interface that is disconnected from image space but rather closely interconnected with the 'something' it is communicating.

In the comparison of different media, there is a difference in spatial versus temporal media, as put forward by McLuhan and many others over the last five decades in the field of media theory (McLuhan, 1964). Though controversial and debated as a theory, the model of spatial and temporal aspects of media has remained a meaningful way of understanding and analysing different media. It is not far-fetched to then state that the image is a spatial form of media, meaning that the communicated information is distributed in space, in this case a two-dimensional image plane (other spatial forms of creation might be sculpture or architecture, using a three-dimensional space). The same information could be communicated through temporal media, such as music or text, where the information A, B, C instead is distributed over time (Fig. 20). A combination of spatial and temporal media is for example video, where the communicated information is distributed over a series of images over time.

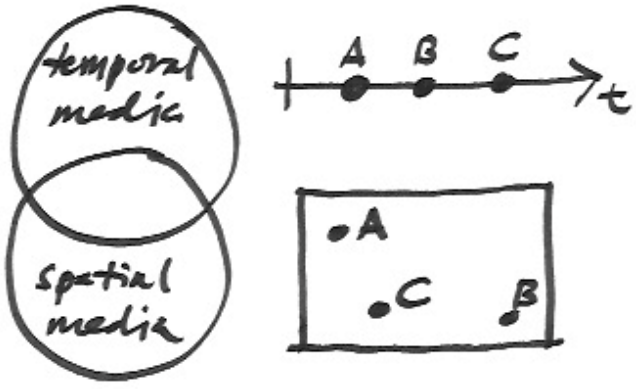


Figure 20. Temporal and spatial media (Wideström, 2015)

This is a very simplified model that needs to be discussed and modified in regard to spatial aspects of temporal media and vice versa. The image as a spatial medium can never be completely detached from temporal aspects, since the image is context dependent, including both where and when the image is used. Also, in the reading of the information A-C in the image, there is a temporal aspect in the order of image elements that can be affected by cognitive factors or biased by cultural conventions, such as for example reading a text from left to right. But most importantly, the image is not an independent artifact frozen in time, but rather part in a communicative process, where negotiations and experiences take place over time.

Here the concept of *gestalt* (the whole nature of something) is vital for understanding meaning and how meaning is produced. The gestalt of the image consists of a) the creation of an idea, b) the representation of this idea in visual elements, and c) the communication of this idea and its representation. Here, representation is used in the broad sense of standing for or presenting something, and not merely re-presenting reality. Representation is the embodiment of ideas, the use of signs that stand in for and take the place of something else. It is important to point out that there is no 'correct answer' for this production of meaning. The representation does not only stand in between the idea and the message, but is rather part of an interplay between creator, image, and viewer. Seeing and creating an image are interdependent processes on mutual terms. Seeing an image is a creative process and as much a competency as creating one.

Using the model for the 'production of meaning' of images in visual culture, it can be said that meaning is produced in the intention, representation and distribution (Sturken & Cartwright, 2018). The image is created with some sort of intention that produces meaning, and also meaning is produced in the way this intention is represented, and lastly how both the intention and representation is distributed. Images might be created without intentional meaning or 'message' but that does not mean that no meaning is produced. And moreover, in the event of an 'author' that has a specific intention that is to be communicated through the image, other (even contradictory) meanings might be produced in the representation and distribution. In analogy with Roland Barthes' famous essay *The Death of the Author* (Barthes, 1977) concerning written text, the same can be said about creating and viewing images. Once the author has represented his or her idea in visual elements on an image plane, the author is no longer there to make further explanations. Then there is also the viewer, reading the image. Meaning is produced in the codes of the discourse, the viewer's expectations and experience of the image, together with the context of when, where and for whom the image is shown. This production of meaning is open to negotiations between the codes, the viewer's interpretations, the context, and the gestalt of the image. For understanding and communicating meaning in artistic work, the use of metaphors is essential. This is also the case for the meaning of virtual space. For example, we use metaphors for travelling or loading when we refer to representations of data. The production of meaning also applies to scientific images and spaces. There are no "neutral" representations of data that do not involve an author with intentions and a viewer with interpretations. This becomes especially clear in advanced interactive visualizations that require complex visual design, such as for neural networks, large scale molecules, or urban environments.

A well-known example that shows this ambiguity is the famous paintings by the Belgian surrealist René Magritte, (Fig. 21-22) also discussed in depth in the book *Ceci n'est pas une pipe* (Foucault, 1983). In this book Foucault talks about the "strangeness" created by the drawing's highly realistic representation of a pipe on the one hand and the words that Magritte wrote below it. This is not a pipe, but it is not just an image of a pipe either. It is "as if" a pipe.

Figure 21. La trahison des images (Magritte, 1929)

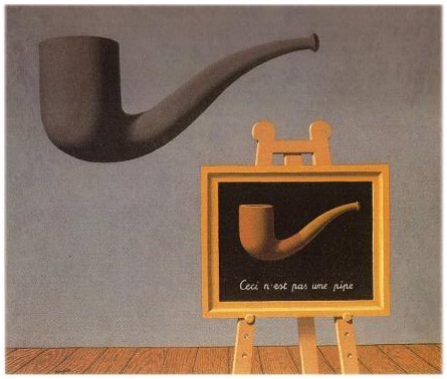


Figure 22. Les Deux Mystères (Magritte, 1966)

So, the image is a spatial medium, or interface, to image space. We can also see the image as a representation of ideas, where meaning is created over time, in a process of negotiations. Seeing the image as a two-dimensional 'shadow' of a multi-dimensional 'truth', Plato's cave metaphor is close at hand. Another ruling metaphor of the image is the 'window into another world'. In the window metaphor, the frame of the picture is the important element as it defines the border between physical space and image space. These two metaphors of the image, the 'shadow on the wall of the cave' and the 'window into another world', share the concept that the image itself is two-dimensional and the space it represents is three-dimensional. The image is then a model of our understanding of the world. This model is drawn on a two-dimensional surface, the image plane, while our understanding of the world is a three-dimensional physical space (actually, there might be more than three dimensions in our physical space but in the scope of this thesis three dimensions suffice). Hence all images are '2D', since they are all limited to a two-dimensional surface, but at the same time all images are '3D' since they are all models of our comprehension of the world as being three-dimensional. Therefore, when viewing and interacting with an image, we interpret the image based on the notions of our physical world. This applies to light, shadow, depth, scale, gravity, and other properties of the physical world that we read into the image. This relation between image and space forms the code of signs and sign relations in visual representation and perception. This code is the semiotic system, the language, of the image. As such it gives both the author and the viewer the 'toolbox' for creating and interpreting images.

This relation between image and space is also the key factor to creating illusions in images. In fact, it can be argued that illusion is one of the founding concepts of the image. As described by Oliver Grau, this illusion works on two levels. First, there is the classic function of illusion which is the conscious play with appearance that can be seen as aesthetic enjoyment of illusion. Second, by intensifying the suggestive image effects and through appearance, this can 'overpower' the viewer's perception of the difference between image space and physical space. "This is a suggestive power that can suspend the relationship between subject and object, and the 'as if' may have effects on awareness" (Grau, 2003). In this second level of illusion, contemporary visual media plays an important role in the 'suspension of disbelief' that supports the experience of image space as being 'real'.

A good example of coherent use of images as an interface to image space is the works of the British architect Gordon Cullen (1914-94). He is known for *Townscapes*, urban spaces that he communicates through series of simple but yet effective black and white drawings (Fig. 23). Cullen is considered to be a model in architectural visualization, by the way he uses the two-dimensional image plane as an interface to the three-dimensional townscape he creates. He also works consciously with the temporal aspects of the image, creating a sequence of spaces in a narrative that form a consistent image space over time.

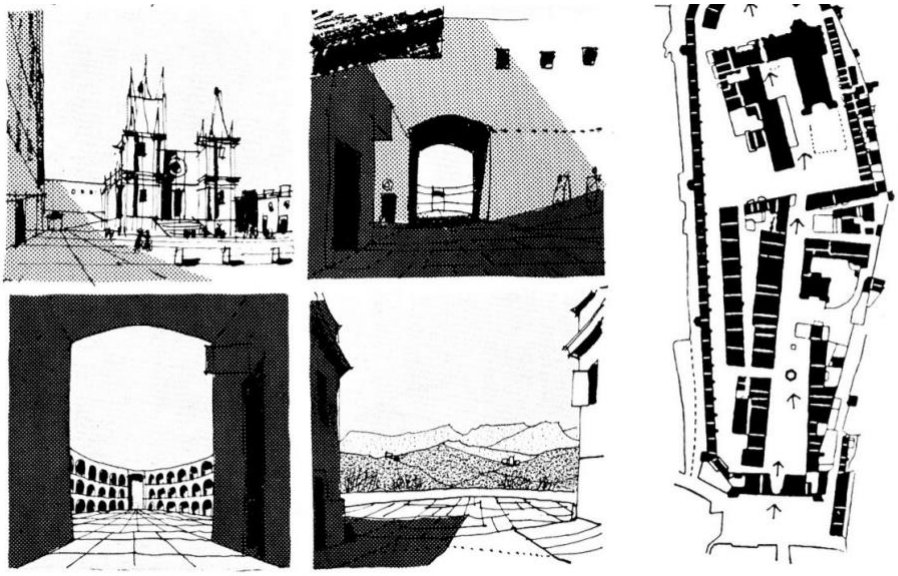


Figure 23. Townscapes (Cullen, 1961)

Seeing the image as a medium means that it is worth considering the properties of this medium. There are two fundamental concepts for the materiality of the image; the canvas and the screen. The obvious difference is that the image in the form of a painting on canvas or a photograph on paper consists of paint or ink, while the digital image consists of light that relies on a computer screen or a projector to be visible. The image on canvas is material, while the digital image is immaterial (as far as light is immaterial) even though it is manifested through physical objects. Both the canvas and the screen use colours on a surface, but the colours belong to different *colour spaces*. Paint with different colours are blended in a subtractive colour space, where for example green and red becomes brown, hence darker (Fig. 24 a). Lights with different colours are blended in an additive colour space, where green and red becomes yellow, hence brighter (Fig. 24 b).

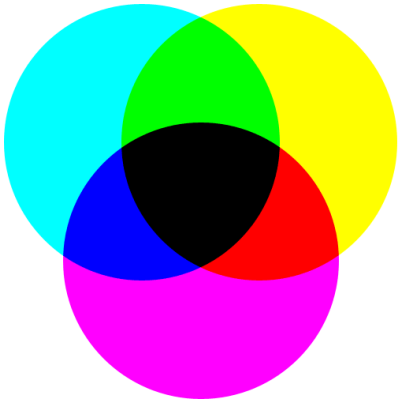


Figure 24 a. Subtractive colour space, paint on canvas (SharkD, 2017). Edited.

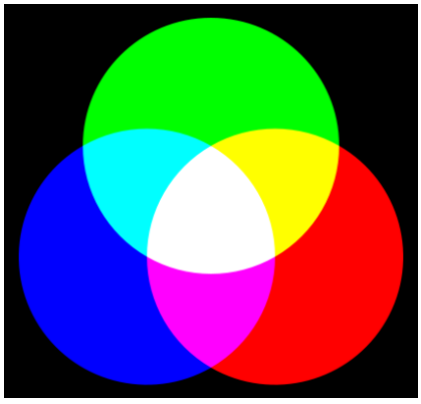


Figure 24 b. Additive colour space, light on a screen (SharkD, 2017). Edited.

This distinction might seem marginal, but it is a fundamental difference that is important for the integration of images in our physical world. In our everyday physical environments, such as our homes and workplaces, there are walls, floors, furniture etc. that all are part of the subtractive colour space. So are the paintings, photos and notice boards on the walls. A screen on the other hand is part of the opposite colour space, which comes in conflict with the ruling colour space of the environment. This is why you need to turn the lights off to be able to see a projected image, which is necessary for access to the additive colour space but makes it harder to see the darkened physical environment at the same time. And vice versa, in an immersive

virtual environment the ruling colour space is additive, making physical objects strange. This difference in colour spaces is an important factor for seeing digital images, and thus digital spaces, as 'something else' or 'another place'.

Other important differences between the canvas and the screen, between physical and digital images, is flexibility and interaction. Physical images tend to be more static; once the painting is finished or the photo is printed it does not change much. There are exceptions of course, with whiteboards that can be edited or physical displays that consist of painted fragments that can flip and change colour. But the overall concept of the physical image is that it is fixed paint on canvas (Fig. 25-26).

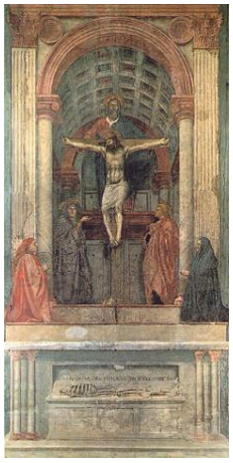


Figure 25. The Holy Trinity (Masaccio, 1427)

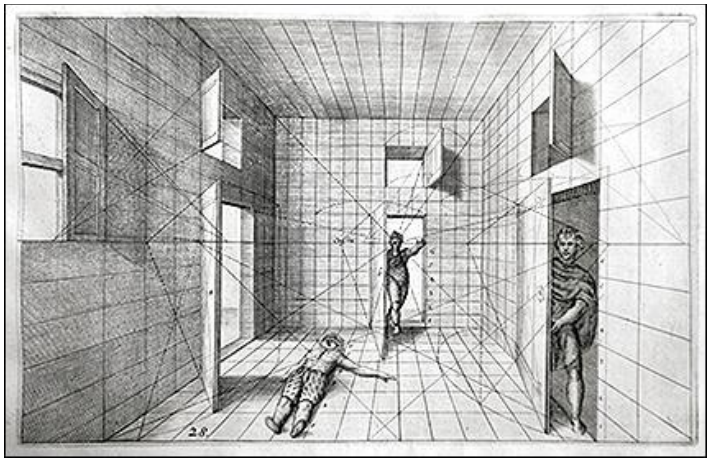


Figure 26. Perspective (Vredeman de Vries, 1604)

On the other hand, the digital image is open to change and interaction. It is fundamentally different from the physical image, not only in the immaterial aspect but in the ways it is produced, used, and understood. The digital image is part of a 'flow' in both creation and representation. The illusion of space is stronger, not in the sense of more realism but in the sense of engagement and interaction with the viewer. Therefore, the digital image has the capacity to become a place to inhabit, rather than just a space to watch. Immersiveness is nothing unique and novel for the digital image, as shown by Oliver Grau, but a higher degree of flexibility and interaction is. Using the maximum capacity of the digital image, it can give the illusion of image space as 'real' (Fig. 28-29).

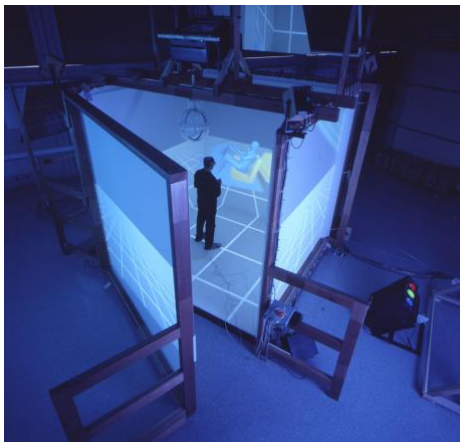


Figure 27. Chalmers VR Cube (Wideström, 1998)

Figure 28. "Picnic under the Golden Tree", (Ljungar-Chapelon, 2008, p. 186-189), Photo: Sandra Andersson

In conclusion, image space is neither physical space nor mental space. It is the abstract space that is accessed through and in images. Structurally, images work as interfaces to image space where the semiotic code forms the language of creating and reading images. Meaning is produced in a communicative process that involves context, space, representation, and interpretation. The experience of image space is formed by ruling metaphors as well as the aesthetics and properties of the image as a medium.

But now, why is not image space sufficient as a definition of virtual space? Objects and spaces that are perceived through images exist in 'another' space and do not occupy physical space so why is image space not virtual? The main argument is lack of interaction and presence. You can look at the Eiffel tower at a postcard and thereby access the image space where the tower stands, but there is nothing to do there and it is not a place to visit, other than mentally. Here, digital media has opened up the interaction with image space, making it accessible not only mentally but also perceptually. The possibility for the user to interact in digital space creates a place for the actor to be present in. So why are not all digital spaces virtual? Well, they might be. The reason for leaving out chat rooms, text-based games, learning platforms and so forth as virtual spaces in this thesis is that they are not visually perceived as spaces. To some extent, space has to be visualized internally in these examples, pretty much like the experience of reading a book or speaking on the phone.

This thesis focuses on the visual aspects of virtuality. For other senses "image space" could be replaced by "sound space" or "tactile space" in an analogue analysis.

Endo-Aesthetics of Virtual Space

My study of RQ1 from this artistic perspective highlights two perspectives; the role of the observer, and the role of aesthetics. In this section, I want to combine these two perspectives. Artworks, as well as virtual spaces, are meant to generate perception. Virtual spaces take form as representations of intentions and are interacting with and being experienced by users (actors, viewers) as a gestalt. These aspects imply that virtual spaces have an object-subject relation with the user, that is similar to the relation of an artwork with its observer. In addition to this, virtual spaces cannot be "looked at" in the same way as a painting or a photo. It is the experience of the virtual space from *within* that gives meaning. This means that we can talk about the *endo-aesthetics* of virtual space, leading to research in media art. In comparison, other forms of representation, such as paintings or photos, are seen from outside the work of art. Gianetti and other media art critics emphasize the shift from an aesthetic model based on "romantic and idealist tradition" with a "rational aesthetic" based on cybernetics and science (Koepnick & McGlothlin, 2009):

> *"The possibilities emerging with digital technologies and their applications in the field of art are inevitably transforming not just the materials, forms, and structures of works of media art, and of interactive art especially, but also revolutionizing the basis of their expressive modes, concepts, and fields of research. "* (Gianetti, 2003)

One of the most important issues of media art research is the relation between the viewer and the work. The pioneer works by Heilig (*Sensorama*) in the 1960's for the head-mounted display, by Weibel (*Inverse Space, Tangible Image*) in the 1970's for the works on observer-dependant worlds, and by Davies (*Osmosis*) in the 1990's for the immersive VR-cave have shown how virtual spaces can work as alternative artificial worlds and their interfaces as windows to another world (Davies, 1995, 1998). These metaphors of windows (and doors) to another world are important for the semantics as well as aesthetics of virtual space, since the observer acts within two parts of reality; the perception of virtual space, and the consciousness of acting in a simulation. The interactions of the observer result in spatial and temporal experiences that then lead to new interactions in this endo-system. However, for the discussion of endo-aesthetics of virtual space it is important to see that the observers' presence in the virtual space is only part of their cognitive processes. Another part is still controlling the presence in the physical (actual) world outside. An aesthetic experience of virtual space is dependent not only on the endo-system but also on the exo-system where the world outside constitutes the context. Therefore, we can talk about a degree of presence on a continuum from virtual to actual, keeping in mind that presence is dependent on physical interaction, whether in virtual or actual space.

This makes the semantics of virtual space quite complex. From a semiotic perspective, the semiosis (production of signs) takes place in an interplay between the experienced virtual space, the observer's physical space and body, the observer's cognitive processes, and social/cultural context. Here Cybersemiotics (Brier, 2013) can be used to analyse these relations. Although the internal observer (inter-actor) is physically located in the real world, he/she contributes to the creation of an artificial model world in which the observer (actor) participates. The observer is in fact "in the picture" while his/her body remains in the actual physical space. This means that a coherent and understandable space for an observer (actor) is dependent on the semiotic code created in an interplay between endo- and exo-system. The experience depends on a double-duality; on one hand between world-observation and self-observation, and on the other hand between the immateriality of the virtual space and the materiality of the physical body. These various levels of reality (endo and exo) show the double game played by endo-semiotics (endo-aesthetics). The observer-dependent reality, that is the reality as the interface between the observer and the other world, in combination with the distinction between internal and external observers' phenomena create conditions for the

development of an endo-aesthetics; the aesthetics of self-reference, of virtuality (the virtual space), of interactivity (the actions and the role of the observer within the system), and the interface (the conception of the world as the interface). As such, endo-aesthetics enable an analysis of virtual space from a media art perspective, where the observer (viewer/audience) is located in the system where it interacts. This concept of "being inside the image" has been studied in the intersection of theatre, film, and VR (Wynants et al., 2008).

This understanding of virtual spaces from an endo-aesthetic perspective evolve from Welsh's concept of an "aesthetics beyond aesthetics" (Welsch, 1997) and from the transition from art to space to system. These spaces can be described from various perspectives as complex, flexible, context-conditioned, hypermedia, and multidisciplinary systems. From the endo-aesthetic perspective these virtual spaces "exist" (make sense and appear) as such only through an active relationship between actors and the (actual or virtual) system. The virtual space as system is always potential and does not exist autonomously. It is constructed based on semantic/semiotic/aesthetic conventions where user has possibility of changing or choosing the "rules of the game" that govern the space. Understanding virtual spaces from an endo-aesthetic perspective enables creation of virtual spaces and realities as systems or model worlds. It supports flexibility of observer-dependent systems, and the integration of internal observers into a virtual system that can be observed from the external perspective.

For example, a condition for the endo-aesthetics of virtual space concerns mixed reality, where both internal and external participants are inside a virtual space in which they exchange messages in order to generate new communication structures that become constitutive elements of the simulated world. An endo-aesthetics of virtual space is reliant on the relativity of an observer-dependent world and the possibilities resulting in reference to internal observers, to the world as interface, and to the relationship between physical and virtual spaces. The phenomena of telepresence and co-presence, where the interactors physically located at different places come together as tele-present inhabitants of the same virtual space, create semantic and aesthetic conditions unique for virtual space. Also, alternative biological interfaces to virtual space open up the interaction to natural processes of the body such as eye movement and breathing. This embodied interaction unfolds the observer's self-perception via the self-controlled activity of the body, giving the interactor the impression of taking part in a natural fashion in the virtual space. As discussed already by Anne Moser in *Immersed in Technology*, his integration of body and space provides new conditions for the semantics and aesthetics of virtual space (Moser et al., 1996).

Virtual space can be seen as a system where art meets science. In this space the actor becomes part of what he or she observes. Distortion triggered by the observer in the reality of the environment is provoked likewise by an actor participating in the artificial, interactive system. In a simulated artificial world, the internal observers have access to certain actions and interventions of which the effects allow them to draw conclusions for their own environment. When these actions, interventions and effects are different in virtual space compared to physical space, a different semiotic code is established. This code forms the fundament for the space and for the agreements and experiences that are made. The complexity of the semantics of virtual space shows how aesthetics, as subordinate to semantics, becomes complex and different from aesthetics in the actual world. Hence the "aesthetics beyond aesthetics" is fundamentally different in virtual space, and form conditions for an aesthetic experience of a setting in virtual space different from the aesthetic experience of the corresponding physical setting.

Visual Semiotics

Visual semiotics is used as a theoretical model in this thesis and constitutes the framework for exploring RQ1 on abstraction level III. Semiotics is the philosophical study of signs and sign relations, where visual semiotics focus on meaning-making in visual signs. The many theories in this field by famous philosophers like Peirce, de Saussure, Eco, Barthes, and Derrida investigate communication, metaphors, analogies, and other concepts that are central in this thesis. In visual semiotics, the signs and sign relations form the code that constitutes the language of communication in images. In abstract terms, this code is one way to define 'image space', the space 'behind' the image. The general notion of communication in visual semiotics is that abstract ideas cannot be 'transferred' directly from a sender (author) to a receiver (viewer) but need to be represented in visual signs that are shown on an image plane and that the viewer then interprets in relation to a context. This follows Charles Sanders Peirce's triadic semiotic model of sign, object and interpretant, summed up in saying that the sign stands *for* the object *to* the interpretant (Fig. 29).

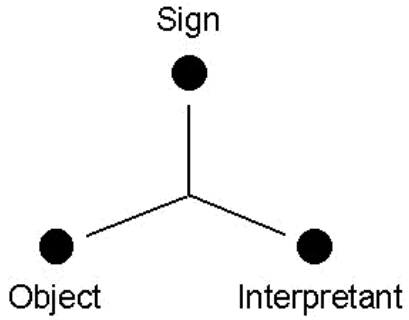


Figure 29. Peirce's triad of semiotics (Semantic scholar, 2007)

The interpretant is then the sense made by the sign, including the effect the sign has to the interpreter and the process of communication and signification. There is not only a one-way implication from object to sign to interpretant, but all three entities are mutually interdependent, creating a genuine triad. According to Peirce's model, there are three types of sign; *icon* that refers through similarity to its object, *symbol* through interpretive habit or norm of reference to its object, and *index* through factual connection to its object (Fig. 29), (Liszka, 1996). This emphasizes that the image is an interface for communication, where the types of signs is the 'toolbox' for representing and interpreting ideas.

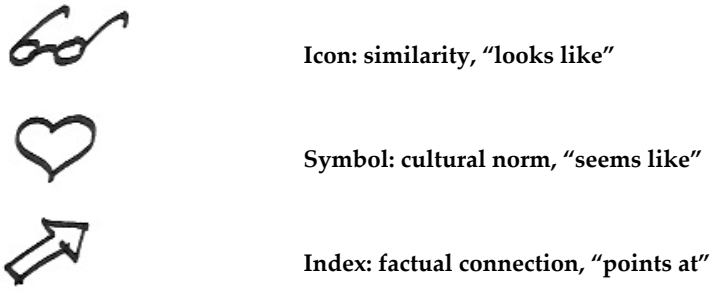


Figure 30. Visual examples of Peirce's three types of signs (Wideström, 2010)

Now, what is the job that this toolbox of signs is to be used for? The short answer is – depth. A major challenge, in both representing and interpreting ideas through images, is that the image plane is two-dimensional while our understanding of the world is three-dimensional. Here, so called 'depth cues' are used to communicate '3D' on '2D'. They include linear and curved

perspective, occlusion, colour perspective, texture detail, similar sizes, light and shadow, and optical effects. This applies of course directly to concrete images, such as architectural visualizations, but also to other images. The depth cues relate to our understanding and perception of physical space, for example the horizon as the founding element in linear perspective, or gravity and body proportions as founding concepts for image composition. The understanding of signs as a toolbox emphasizes the function of the image as an interface to image space. It is important to point out that seeing an image is as much a competency as creating one. Since icons refer to object by similarity, the viewer needs to recognise this similarity. Since symbols refer to rules and conventions, the viewer needs to understand these rules, and lastly, since indices refer to factual connections, the viewer needs experience of these connections from the physical world. The image is an interface to image space, and as such it is not trivial to master, neither as an author nor a viewer.

A Semiotic Perspective on Space

Semiotics (the theory of signs and sign relations) can be used as a powerful tool to analyse language, meaning not only written text and spoken words but also other forms of representation such as music and architecture. Semiotic analyses reveal the structure of the language and work as a means of abstraction. A problem with these analyses might be that the representations are reduced to an abstract structure that explains the system of semiotics more than it explains the actual representations. In a semiotic analysis of a particular architectural space, the result in the form of tables and arrows has little to do with the aesthetic and social qualities of this piece of architecture. However, semiotics is fruitful as a model of thinking about spaces and as a way of seeing the relations between different spaces. The physical-virtual divide can be resolved by looking at common structures in order to unify physical and virtual space. In order to make the semiotic analyses richer in this text they are combined with views on how signs are produced (semiosis) and how representations are interpretated (hermeneutics). So, with one foot in semiosis and the other in hermeneutics, the thesis now moves into this analysis with a mission to identify some of the most important relations between physical and virtual spaces.

Theoretically, the semiotic perspective in this article originates in *sign relations*, as developed by Charles Sanders Peirce (Liszka, 1996), in the end of the 19th century. According to Peirce, a sign is always related to an object and its interpretant in a genuine triad (Fig. 29). In the sign process the interpretant then becomes the object in the next triad and so on. The culturally defined system of relationships can be regarded as the *code*, giving the conditions for the connections between interpretants and objects. In different code systems, the links between interpretants and objects are consequently different, but also within a certain code there are a number of plausible connections. Each chain of triads is therefore one of many possible chains in the production of signs.

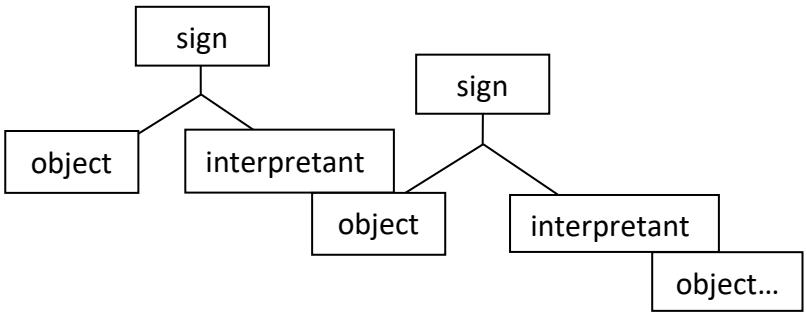


Figure 31. Peirce's triad and the sign process (Wideström, 2007)

The other fundamental analysis of language was made, also in the end of the 19th century, by Ferdinand de Saussure[31], the father of structuralism in linguistics and semiotics. He introduced the idea of the *signifier* (the written or spoken word) and the *signified* (the thought or concept). This idea does not imply that the relation between signifier and signified is absolutely fixed, but rather open to arbitrary connections. What makes de Saussure's theory structuralist is instead the notion that language can be analysed as a formal system of differential elements. Both the signifier and the signified have a common referent (the physical object), meaning that there are also non-referential signifiers, such as the word "ghost". This semiotic model is interesting to use in the study of virtual spaces, where both referential and non-referential signifiers, also known as "floating signifiers", can be observed (Anderson & Saussure, 2018). These floating signifiers play an important role in visual arts and virtual spaces, in the way that they leave the visual expression open to interpretation from the viewer.

In this section of the text I will now focus on the development of ideas of language and semiotics from the 1960's and onwards, discussing the relevance on architectural space by the works of Umberto Eco and Jaques Derrida. In 1979 Umberto Eco published his comprehensive *A Theory of Semiotics* (Eco, 1979), where he separates a theory of codes (signification) from a theory of sign production (communication). In the introduction of this work (p. 8) Eco states "semiotics studies all cultural processes as processes of communication". It is this *act of communication* that creates meaning and knowledge. Architecture can be seen a cultural phenomenon driven by cultural processes. This assumption implies that all meaning of architectural space come from acts of communication of architectural signs, hence all expectations, experiences and understandings of space that emerge from interactions between humans and architectural space. Eco defines sign as "The sign is used to transmit information; to say or to indicate a thing that someone knows and wants others to know as well" (Eco, 1984, p. 27). This definition follows the communication model:

Source → Sender → Channel → Message → Receiver

Still, the message may never signify if the sender and receiver do not share a common code, a common language. This means that the architect's intentions may only be experienced if he recognises the culturally defined structure of architecture, the code. Since the architect is highly integrated in the production of signs, he is also a part of the code. However, the intentions originate in a certain time in the context of a certain code, while the materialised (frozen) intentions remain fixed over time. As the code constantly develops, this means that there will be inevitable discrepancies in the interpretations of this piece of architecture. This highlights an important difference between physical and virtual spaces, since virtual spaces are digital and as such more flexible than physical spaces. Setting aside the importance of the architect's intention (which can be debated), architectural space inevitably creates a physical and contextual framework for the human-to-human communication. Following this idea, the space is a result of the code and simultaneously constitutes the code, the culturally defined system of relations. One of Eco's most important contributions in the development of Peirce's theories is the extension of semiotics so that a sign stands for something else in an even wider sense. In *Theory of semiotics* (p. 166) Eco states that "even ideas are signs", giving semiotics a strong philosophical dimension. In relation to architecture this entails that also architectural concepts and ideas are architecture. In this extension of semiotics, he also includes perception as sign (p. 77), making a closer connection between semiotics and science. In his work he widens the sign concept, at the same time as he actually questions the whole notion of sign. According to Eco, signs need not to have specific referents but may be open to different meanings in different

[31] An English translation of de Saussure's most important work is *Writings in General Linguistics* (Saussure, 2006)

contexts. He states, "The idea of the interpretant makes a theory of signification a rigorous science of cultural phenomena, while detaching it from the metaphysics of the referent" (p. 70). But how does that relate to architecture and experience of space? As a complement to Peirce's theory, Eco adds important extensions and arbitrary dimensions to semiotics. However, when looking at specific examples of virtual and physical spaces, Eco's non-referential models do not relate to the actual expectation, experience and understanding of space.

Continuing the ideas about reference and origin in sign production, the contributions of Jaques Derrida[32] in the 1960's and 70's redefined the ideas about complexity and structure. His work made an important impact on not only literature and art but also architecture in the late 20th century. As a poststructuralist, he has elaborated a theory of deconstruction (of discourse and of the world) that challenges the idea of a frozen structure and advances the notion that there is no fixed structure or centre, no unifying meaning. Deconstructivism in architecture uses fragmentation as the main theme, dismantling the basic elements into bits and pieces.[33] The concept of "text" in Derrida's work also includes other representations, such as visual art, music and architecture. Here, virtual spaces as seen through Virtual Reality become relevant examples of "text" of deconstruction, where form, content, and structure are flexible and where the text does not exist without the reader.

Derrida rejected all binary structure such as signifier vs signified, perception vs understanding, culture vs nature, and, if he had lived today, he most surely would have opposed to the real/virtual duality. His conception of sign opposes to that of de Saussure, so that the sign itself is *indecidable*, not only arbitrary in the relation between signifier and signified. According to Derrida,[34] the sign is caught in between the *expression of content* and the *indication of something else* (Derrida, 1967). The different signifieds to which a signifier might refer also affect all other signifieds. This means that Derrida in some aspect concludes with Eco that the signifieds work as signifiers (ideas as signs), even though Derrida's questioning of the sign goes as far as destroying the whole concept of sign. In his view, the idea of a direct connection between signifier and signified is no longer valid, and instead we have infinite shifts in meaning transferred from one signifier to another. Guillemette and Cossette write in their article *Déconstruction and Différance* that "This infinite chain from signifier to signifier results in a never-ending game and opens the text, displaces it, sets it in motion" (Guillemette & Cossette, 2006). Derrida means that (the process of) writing is the *signifier of the signifier*,[35] placing writing outside the written language. At the same time writing is part of the language it signifies, meaning that writing is both inside and outside language. This idea is interesting in regard to the creation of architecture. It places the architect both outside and inside the language of architecture, unfolding architectural space as both a tool and a world.

Derrida's ideas are interesting in relation to interpretation of space since he points out that the sign process is a *game* that constantly leads to new interpretations. Derrida introduces the concept *trace* to explain this view of the sign process, where the interpretation itself leaves traces that affect the process. Though criticised for being deliberately obscure, there is no doubt that Derrida's postmodern attack on structuralism has contributed to a more open-minded view on the complexity of creative work and interpretation of art. His notions of space become relevant in relation to the understanding of contemporary virtual spaces. In this thesis, Derrida's ideas are also reflected in my method to use relations between particular examples

[32] In 1967 Jaques Derrida published his three fundamental collections of work: *Of Grammatology*, *Writing and Difference*, and *Speech and Phenomena* that originated in the philosophical work of Husserl and Heidegger.

[33] Architectural works by for example Frank Gehry and Rem Koolhaas are generally considered to be in the realm of deconstruction.

[34] *Writing and Difference* as explained by H.J. Silverman (1998) *Cultural Semiosis: tracing the signifier*, p.6-7.

[35] *Of Grammatology* as explained by H.J. Silverman (1998) *Cultural Semiosis: tracing the signifier*, p. 7-8.

to discuss and evaluate general ideas. It is in the interplay between different experiences that understanding can be created.

A semiotic view on the relation between reality and virtuality reveals that this duality of "real" versus "virtual" already exists in the structure of language. We can say that an object (or representation) exists, which can be defined as "real", but to say something about *what* it is that exists is in a sense "virtual". Using Derrida's view the object is caught between the real and the virtual, in an interplay between existence and interpretation. In the context of architectural space this means that both physical and virtual architecture have aspects of virtuality. Looking at my examples of physical-virtual spaces in the cases below it becomes clear that there is no equivalence between real and physical, or between unreal and virtual.

Concluding the exploration of RQ1 from a semiotic perspective, virtual space can be seen as the 'code', forming the conditions for how the visual representations are understood. The understanding of signs as a toolbox emphasizes the function of the image as an interface to image space. Floating signifiers play an important role in visual arts and virtual spaces, in the way that they leave the visual expression open to interpretation from the viewer. Virtual spaces as seen through Virtual Reality become relevant examples of "text" of deconstruction, where form, content, and structure are flexible and where the text does not exist without the reader. Physical spaces are more fixed, so that the physical signifiers need to reconnect to other signifieds in the constant development of new codes. This highlights an important difference between physical and virtual spaces, since virtual spaces are digital and as such more flexible in form than physical spaces. However, the physical-virtual divide can be resolved by looking at common structures in order to connect physical and virtual space.

4. A Seeing Place

This chapter explores my second research question, RQ2, how metaphors support the relations between physical and virtual space, and my third question, RQ3, how a common place for the physical and virtual can be formed. I start from the higher levels of abstraction, by discussing the relations between space and place and then connect metaphor to space and place. From there, I move to the intermediate levels of abstraction, when focusing on the concepts of theatre and the particular stage metaphor.

Space and Place

Space and place are two fundamental concepts in Geography, as well as in our everyday descriptions of the world. Our planet exists in space, there is enough space in our house for guests, the town square is spacious, and so on. Space is generally used to describe the structure, dimension and location of something. Place is more used for personal experience and human interactions, as in "there is no place like home" or "the town square is a place to meet".

Chinese geographer Yi-Fu Tuan puts forward an experience-based perspective on these concepts in his book *Place and Space* (Tuan, 1977). He considers the ways in which people feel and think about space, how they form attachments to home, neighbourhood, and beyond, and how feelings about space and place are affected by the sense of time. He generally proposes that place is about security and space is about freedom: we are attached to one and long for the other. His ambition is to both describe the concepts of space and place and also suggest how scientists and architects, like urban planners, can make use of these concepts in order to design a more human habitat. This approach is in line with the ambition of this thesis, looking at relations between different spaces with the ambition to contribute to the practices of architecture and interaction design. The interesting aspects of Tuan's ideas in relation to my analysis is how he shows that 'space' is described in abstract and objective terms while 'place' is more concrete and subjective. Basically, for a place to exist, there is need for a space and a human being attached to it.

As discussed in the previous chapter, physical space and virtual space are entities that exist in reality as subsets of the wider entity of space. The hierarchy of physical space and virtual space is equal, so one is not a subset of the other. The co-existence of physical and virtual space makes it possible to experience both physical and virtual space, even simultaneously, creating a physical-virtual space in a phenomenological sense.

In virtual space, as well as in physical space, there are places to inhabit and attach personal thoughts and feelings to. Using Tuan's analysis, your home in a *Sims* game is your place in the world, while the whole game world is the space of possibilities. Even though Tuan emphasized tangibility and physicality in his definition of place some four decades ago, we should now accept the multimodal and interactive experience of virtual space as sufficient conditions for creating a place. Also, place is less about sensory input and more about the thoughts and feelings that are attached to it. As mentioned before in his thesis, "Real events happen in real places in virtual spaces" (Kolb, 2006). It is the human actions in and human connections to a space that define it as a place, regardless of the materiality of the space.

The hierarchy of space and place is also not given. At first glance, one assumes that a place would necessarily be part of a space, with certain requirements fulfilled, such as a neighbourhood being part of a city. However, the opposite can also apply. The most obvious example is the home that is a place that consists of a number of spaces, for example kitchen, bedroom, garden, and so on. The conceptual difference between space and place is not about size, but rather about personal attachment, human interaction, and experience. I use 'place' as a term for a space, or a set of spaces, where emotional and intellectual agreements are made

between actors/users and the space. Later in this thesis I will give examples of places that consist of both physical and virtual spaces. To extend the concept of place, I will introduce the 'stage' metaphor.

Spaces are here seen as structures that can be defined both by objective measures and subjective perception. This concerns both physical and virtual spaces on equal terms. It is then by human connection, emotional and intellectual, that spaces become places. Using conceptual metaphors, these places can become for example "homes" or "neighbourhoods" that are used as agreements on how to negotiate and interact in different situations. More specifically, this thesis introduces the Stage metaphor as a unifying concept for physical-virtual spaces that are to be understood as meaningful places for human interaction and experience. In a simplified model this can be analysed as:

SPACE → Human Connection → PLACE → Agreements and Metaphors → STAGE

Using this model, all stages are places and all places are spaces, but not the opposite. Moreover, 'place' is the concept that connects 'space' with 'stage'. A more thorough presentation of the Stage metaphor, and how it can be of importance and use, follows in the next chapter.

A specific type of *Place* that is studied in this thesis is the *Stage*. The idea is that a stage is a place for staging, that is presentation of a scene, a drama, or a performance. As discussed in the famous book *The Presentation of Self in Everyday Life* (Goffman, 1956) all human interaction can be seen as staging of a scene with roles, using the analogy of theatre: an actor performs on a setting which is constructed of a stage and a backstage, the props in both settings direct his action, he is being watched by an audience, but at the same time he is an audience for his viewers' play.

In this thesis, I will focus on scenes that are intentionally staged for interaction in and with physical-virtual spaces. It could for example be a science center or a museum, where physical and virtual spaces co-exist in order to show certain environments, scenes, or events. The idea is to highlight the need for a unifying concept for both creating and using these spaces. *Stage* is here used metaphorically, with the intention to open up the physical-virtual space for a way of seeing users as actors, the space as a stage, the limitations as a set, events as part of a drama, clothes as costumes, and so forth.

Later in this text I will introduce the *Stage* as a metaphor for a space where this interplay between reality and virtuality can happen, and also as a space for the connection of physical and virtual space. In order to introduce the Stage metaphor, I first describe how I use the idea of *conceptual metaphors* that can work as foundation for further agreements and interpretations, in the use of more metaphors. The idea is that when the Stage metaphor is introduced, other concepts such as roles, scene, actors, and audience, will be used and understood from the Stage as ruling concept. Then I present how a stage is constituted and how it works in the context of theatre. The purpose is to show the many dimensions of the concept, both structurally and artistically, in order to give a wide spectrum of connotations for the Stage metaphor. This description includes both classical and modern theatre, and the different practices and theories that are connected to these different forms of theatre.

Metaphor

A metaphor (Greek *metaphero* "carry over" or "transfer") works as an analogy between two objects or concepts. An object can be a word, an image, a 3-dimensional shape, a gesture, a musical chord or any other form of representation. The typical example is the word "rose" which is used as metaphor in for example the sentence "you are a rose", implying that the other person is loved, special, fragile and so forth. Taking the analogy more concretely, "rose" could also mean "has a wonderful scent" or even "has thorns", making "rose" a metonym (a substitution of signifiers based on understood association). The word "rose" has of course also religious and other meanings that can be understood from the discourse and the context of the sentence. The general view is that metaphors are poetic in their function and have the capacity to enhance or 'give life' to the language.

Cognitive linguist George Lakoff explains that metaphorical expressions are essentially not in language, but in thought: "They are general mappings across conceptual domains. In short, the locus of metaphor is not in language at all, but in the way we conceptualise one mental domain in terms of another" (Lakoff, 1993). The general theory of metaphor is therefore, according to Lakoff, given by characterizing such cross-domain mappings. And in that process, everyday abstract concepts like space, time, states, change, causation, and purpose also turn out to be metaphorical. Empirical results (Lakoff & Johnson, 1980) show that everyday metaphor is characterised by a huge system of thousands of cross-domain mappings, and the word *metaphor* has come to mean *a cross-domain mapping in the conceptual system.* The term *metaphorical expression* refers to a linguistic expression (a word, phrase, or sentence) that is the surface realization of such a cross-domain mapping. Lakoff explains how *conceptual metaphors* have the power to make us understand one concept in terms of another. To exemplify this concept, we could look at everyday metaphors like "way" or "road" that are used to describe events and choices over time: "I am on my way to change job", "I am standing at a crossroad", and "this is the road to success". The interesting aspect of these metaphors is not that "crossroad" is an analogy for "choice" (the surface realization according to Lakoff) but rather that they all together show that "journey" is a metaphor for "life". We understand these metaphors because we understand the reference to the general idea, the conceptual domain. Through these metaphors, we understand life as a *spatial concept*, a path through a landscape of "ups and downs" and events or people that "cross our path". Once we have learnt this idea, it is impossible to un-learn it and we bear this association with us, so that we connect the two concepts together.

Wittgenstein discussed the concept "seeing as" in order to describe how we interpret images and language (Wittgenstein, 1953). In the well-known example with the "duckrabbit" picture (Jastrow, 1899), drawn by psychologist Joseph Jastrow, there is a double meaning and two ways to read the image, so that it is impossible to see both interpretations at the same time. It is possible to change from one interpretation to the other, but at a given moment one can only see a duck or a rabbit. What Wittgenstein points out is that this internal change has an impact on the external world. In other words, changing the way that we see the world changes the world. This phenomenon is also the case when it comes to creation and interpretation of different types of spaces. Since the theme of this text is the relation between physical and virtual spaces, reality and virtuality, I will pursue this conceptual dialectic, even though there are many other ways to classify spaces. In this text I discuss and exemplify how we see spaces as physical *or* virtual, the duck being physical and the rabbit virtual. This means that we have different models for the understanding of a physical space than what we have for a virtual. When we are confronted with a physical-virtual environment we are not able to understand it as one space, but rather as a set of different spaces.

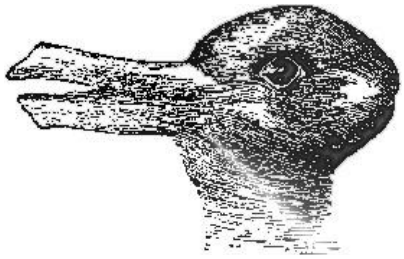


Figure 32. Duckrabbit (Jastrow, 1899)

Since the emergence of virtual space we have used different metaphors for the physical and the virtual, so that physical and virtual space are essentially two different conceptual domains, using Lakoff's term. That means, that the unification of the physical and virtual space cannot take place in a hermeneutic sense. We do not understand spaces as just space, but rather as different conceptual domains.

In physical spaces we prefer metaphors in architecture that refer to nature and culture, such as "the Sydney Opera House is a seashell". This particular example of metaphorical expression carries over not only the resemblance of a seashell but also that seashells have to do with listening to music, along with the interpretants of tranquility, life-containing, and protecting. The Sydney Opera House tells us that we understand music as an experience of nature, not just culture. Metaphors from the world of architecture are also used in theories in science and philosophy, such as "this concept is the foundation" or "a framework for this theory" and so forth. The cross-domain links that these metaphors create work both ways, so that architecture is considered as a formation of ideas and knowledge. Historically, metaphors came into play as an important part in the creation and interpretation of architecture in the Post-Modern era. In 1972 architect Robert Venturi coined the concepts "duck" and "decorated shed" as two models of how metaphors can work in urban space (Fig. 33), elaborated further in his most well-known work *Learning from Las Vegas* (Venturi et al., 1977). The duck and the decorated shed embody symbolism/iconography in architecture in two distinct ways, which is an analysis that has formed the way we read physical spaces today. However, this does not mean that architecture did not work on a metaphorical level before 1970, just that metaphors have been more focused on since then.

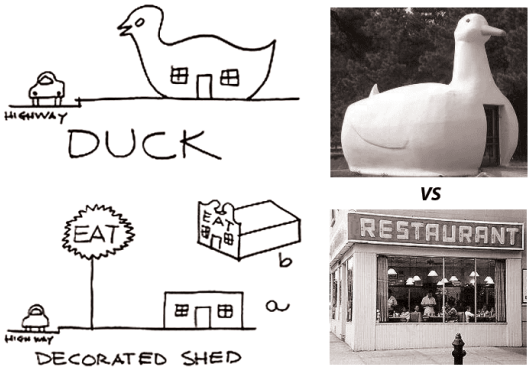


Figure 33. Duck and Decorated shed (Venturi, 1972)

Virtual spaces, on the other hand, lean on a set of metaphors that relate to a different context, sprung from the early ages of cyberspace and virtual reality. We see metaphors like "diving into the virtual environment" and symbolic images of grids, flashes and lights as signifiers for spatial properties like distance and atmosphere.[36] In our everyday life we "explore" and "navigate" on the Internet, words that are viable for interaction in physical space as well but then concerning outer space travel or other adventures, not for just everyday physical

[36] The signifiers for different aspects of virtuality are described in *A Poetics of Virtuality* (Eriksson, 2017).

interaction like buying tickets or socialising with friends. Another use of metaphors in virtual space is when images of analogue objects like old telephones, trashcans and folders represent communication, deletion and organization. These images were introduced as icons some thirty years ago when a telephone actually had that appearance and function, but they survive now only as pictorial analogies in digital representations.

One could argue that we already do use the same metaphors in both physical and virtual spaces, such as "this environment is a nightmare". These are general metaphorical expressions where "environment" can be replaced with "X" and do not relate particularly to spatial aspects. Another similarity between metaphors in contemporary virtual and physical spaces exists in the notion of *identity*. Companies and organizations of today strive to integrate their identity (soul, core value etc) in both their physical and virtual environments as a strategy of "branding". This identity is represented consciously in metaphors that are used both physically and virtually. Also on a private level, people use similar symbols and analogies to create or strengthen their own identity both physically (for example in clothing and home decoration) and digitally (in facebook profiles, iphone apps etc). This connects to the notion of a digital subject, a human or non-human entity represented or existing in the digital realm (Windley, 2005). Still, by branding our personal physical-virtual identity we merely "decorate" our subjects with metaphors on an object-level. We do not conceptualise one mental domain in terms of another.

What is then the importance of metaphors? Paul Ricoeur analyses the metaphor in three points of view: the *form* of metaphor as a shape or figure of speech, the *sense* of metaphor as an origin of semantic meaning, but most importantly the *reference* of the metaphorical statement as "the power to redescribe reality" (Ricoeur, 1977). This analysis shows a transition from semiotics to semantics to hermeneutics, that is, from sign relations to interpretation and understanding of the world. It means that every metaphor has a reference to a discourse, and that the *intention* of this discourse cannot be reduced to a semiotic analysis of the signifier and the signified. In my reading, Ricoeur wants to say something about the world, not only about sign relations. He goes beyond the classic 'semiotic versus semantic' viewpoint and states that "the sign owes its very meaning as a sign to its usage in discourse" (p. 5), showing his interest to apply the abstract world of semiotics to things, spaces and situations. Furthermore, his view extends the linguistic context so that metaphors do not only involve written language but all forms of representation. According to Ricoeur metaphors creatively transform language, language here being understood in a broader sense, i.e. "the language of architecture" or "the language of music". Metaphors are mainly talked about as used in text, but when Ricoeur talks about text he means the "production of discourse as a work" (p. 259-261). To analyse this concept further he categorises the production of discourse as a work into three categories: firstly the composition or *arrangement* of the parts, secondly the codification of the work that tells what *genre* the work belongs to, and at last the result of the production as a singular piece of work that has a particular *style*. In all three categories, the metaphorical statement can work actively with the arrangement, the genre and the style of the work. Ricoeur then uses the idea that the structure of the work can be seen as its sense and the world of the work as its reference. We can then regard hermeneutics as a theory that deals with the transition from the structure of the work to the world of the work. Metaphors come into play here in an interesting way, since they are in essence vehicles of meaning and point at the relationship between what is displayed and what is suspended.

Reading the notions of Ricoeur and Lakoff together, metaphors are not merely rhetorical ornaments but they have genuine cognitive import in their own right. In this line of thought I see metaphors as a method of invention and creation. By finding metaphors in the relations between the physical and the virtual that can combine and include both reality and virtuality we can move towards the unification of physical and virtual space, in a hermeneutic sense.

The Case on Stage

> *"The theatre is dark and silent. There is just the soft sound of the audience's breath and whisper, a cough and a coat being folded. Then a sound of wind and rain is heard, first vaguely as if from outside but then stronger so it is clear that the storm has come. Then suddenly, a spotlight floods the stage from the right. Then another one from the left. The stage is empty, but for a worn case right in the center. All eyes are focused on the case, as the lid slowly opens…"*
>
> (from my notebook, September 2015)

The theatre is a place for expectation, agreement, attention and experience, a place for seeing. It is a place for drama. This drama appears in the theatre when actors and spectators meet in a co-experienced narrative in a co-experienced space. The interface for this co-experience is the *stage*, the negotiated platform for theatrical expression and experience. Prominently, the actors express the drama on stage and the spectators experience the drama from the auditorium. However, in theatre the actors also experience, and the spectators also express. All four aspects of theatre that are brought up here – expectation, agreement, attention and experience – are dependent of both actors and spectators. This means that the border between actors and spectators can be resolved to a certain extent, physically as well as conceptually. One can say that it is the interaction and co-presence of actors and spectators that create the "here and now" quality of theatre.

Defining the stage as a space, there is a set or a scenography, creating a focus for the shared experience of the drama. The stage is either particularly designed for a specific drama or a chosen or given space where the drama takes place. Either way, the stage creates expectations of what to happen, requires a certain amount of agreements to be understood, works as the focus point for attention, and is the place for co-experience. The stage can be defined by different physical elements, such as back drops, décor walls, curtains, platforms, ramps, stairs, doors, furniture and props that altogether create one or several physical spaces. In addition to these physical elements, the stage can also be defined by lights, projections, and sounds. These phenomena might be produced by digital or analogue tools, but either way, they can create a sort of virtual spaces that co-exist with the physical spaces. In scenography, space is created by claiming and convincing, using artistic means, rather than following design rules and guidelines.

On stage, magic can happen. Spaces and objects can appear and disappear in an instant. Actors and spectators can travel in space and time. Scale factors can change. And opening the smallest case, anything can appear.

Stage

In this text I propose the *Stage* as metaphor for creating, seeing and interacting in physical-virtual spaces. In understanding what a Stage is, its concepts and components, I hope to show how the Stage can work as a model for creation and interpretation of physical-virtual space. The idea is to use the Stage as the engine for cross-domain mapping between spaces in the way that Lakoff describes, as well as the arena for arrangement, genre and style in the line of Ricoeur's idea. More specifically, I will use the Stage as a *conceptual metaphor* as a way to resolve the physical-virtual divide in situations where we are confronted with physical-virtual space, as creators, users and actors. The ambition is to contribute both theoretically and practically to the domains of architecture, theatre and interaction design.

The stage is a space for agreement, attention and experience. This space becomes a place through human connections, that is the agreements that actors and audience make with each other, the set, and the play. The actual drama is formed in this process and depends on the attention of the audience, since the actors and the audience communicate in the same physical space. The experience can therefore be said to be both shared and individual. There are common agreements and a common language, while there are individual interpretations of the performance of the play.

Using *Stage* as metaphor for the physical-virtual space, the reference to theatre is central. The word theatre comes from Greek *theatron* meaning "the seeing place" (Holm, 1969). From this conceptual metaphor of seeing, we understand other metaphors, such as "clear" or "looking into". "See" can here be understood both as "look" and "understand". The physical form of the classical theatre was developed with the purpose to let the audience be able to look at and hear the actors on stage. At the same time, the text-based story that constitutes the fundament of classical theatre has the purpose to create understanding about our real world through the experience of a fictional drama. Even though the classical theatre is shaped by a well-defined border between the stage for the actors and the auditorium for the audience, the process of "seeing" takes place in the whole space, involving both actors and audience in a communicative process and a shared experience.

> *"Theatre, also spelled theater, in architecture, a building or space in which a performance may be given before an audience. The word is from the Greek theatron, "a place of seeing". A theatre usually has a stage area where the performance itself takes place. Since ancient times the evolving design of theatres has been determined largely by the spectators' physical requirements for seeing and hearing the performers and by the changing nature of the activity presented."* (*Encyclopaedia Britannica*, 2018)

Physically, the play itself takes place on stage. The stage is formed, designed and lit using different sets and lights as a representation of the play. The purpose of this *scenography* (set design, stage design) is to support the narrative and to give space to the actors and to the play. The actors stand, move around, talk and gesture on the stage in relation to the audience in the auditorium. This means that the space of the play is larger than the stage. It is the interplay between the actors, the script, the audience and the stage that forms and gives life to the play. From a semiotic standpoint this interplay works in a structure of sign relations that form the code of theatre. We can see this code as a space, and this space is theatre, the seeing place. Hermeneutically, the stage is a space for agreement, attention and experience. Different agreements are made between audience, actors, set and story that form the conditions for the drama. This chain of new agreements and experiences form the actual drama.

In theatre, the stage is a designated space for the performance of theatrical productions. The stage serves as a space for actors or performers and a focal point for the audience. As a physical space, the stage consists typically of a raised or framed platform. It can have different geometric shapes and different directions and relations to the auditorium. In some cases the

stage may be temporary or adjustable but in traditional theatres the stage is often a permanent feature. There are three basic types of stages that are different in use and relation of the auditorium. The most common form is the "proscenium stage", where the audience is located on one side of the stage with the remaining sides hidden and used by the performers and technicians backstage (Fig. 34). Here the audience looks at the stage through the proscenium that works as a frame or window into the stage. In front of the proscenium there is often a part of the stage that extends out in the auditorium. In the circus or amphitheatre, the audience is located around (or almost all around) the stage, that is the center of the space. The third type of stage is specifically designed spaces or already existing spaces that are adapted as a stage, such as a market square or a factory. The common feature to all these types is the ramp. The ramp is the border between the stage and the auditorium and defines the stage as a separate space. This border can be a significant physical obstacle or a more subtle line between the actor and the viewer. The auditorium is the space for the spectators, where they sit or stand and watch the play. The spatial relationship between the stage and the auditorium is important for the interaction between actors and spectators and for the experience and understanding of the play.

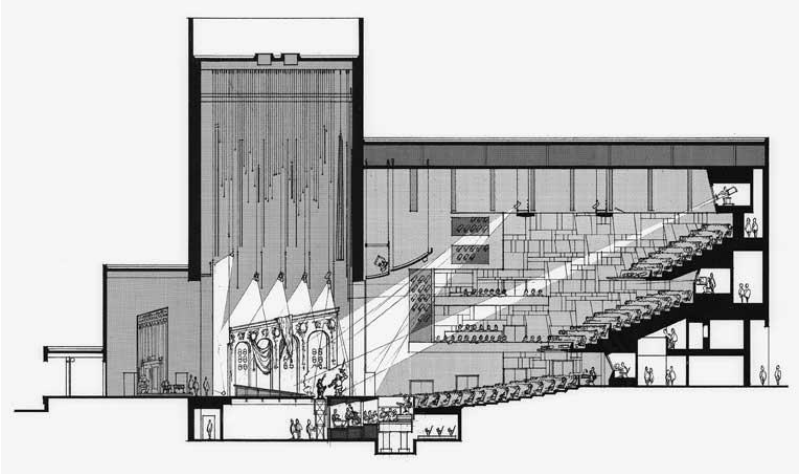


Figure 34. Traditional proscenium theatre with stage and auditorium (Izenour et al., 1996)

The stage proscenium, backdrop and ramp work as the three-dimensional physical frame for the space of the performance. Objects, actors, light effects etc. within this space are "in play" while objects outside do not belong to the space. The difference between inside and outside of this frame is fundamental for the understanding of the stage, and the frame boundary can be as precise as the frame of a painting. This means, for example, that if an actor can takes only one step outside the stage he or she is no longer part of the designated space. The boundaries of the stage are given implicitly to the audience by actors, the director and the stage designer and work as a contract or agreement between the audience and the performance. This agreement can also be seen as a result of a negotiation between the audience and the performance. This negotiation can become especially important in certain situations, such as for novice visitors to a theatre, in unusual stage settings, or when the contract is "broken" by one party and needs to be re-established.

Framing this stage, there is a set. The set is uniquely designed or adapted for a specific play and theatre by a set designer (scenographer) in collaboration with the director and often with a separate light designer, sound designer, and costume designer. The set and the way it supports the drama is the *scenography*, which can be defined as "the manipulation and orchestration of the performance environment" (McKinney & Butterworth, 2009). The scenography is a composition of physical elements (boards, curtains, walls, paint, furniture, costumes, props etc) and immaterial elements (light, sound, projections) that together shape

the extensions of the stage. These elements are arranged in order to support the agreements and experiences of the drama. The scenography is a space for multimodal experience, where auditory and tactile interactions play important parts, even though the visual aspects are most dominant. In summary, the components of the scenography work in symbiosis with the play, the performance, the actors, and the context to form the experience of both the audience and the actors.

Figure 35. Modern stage with auditorium, set and props (MeX Theatre, 2010)

In modern forms of theatre, the division between separate spaces for actors and audience has been partly dissolved, with the use of other than traditional theatres as places and creating new and more interactive stories. Also, the staging is different with more focus on involving the audience (Fig. 35). This has made the modern theatre even more of a shared "seeing place". Modern theatre, as it emerged as avant-garde or performance theatre during the 20th century, had an innovative approach to the relations between actors and audience as well as the stage, the story, and the actors' bodies. The stage is not only seen as a "back-drop" to the actors, but rather a shared space with the audience. The audience is invited on stage and the actors are interacting with and involving the audience. The "seeing" has become less distant and involving more senses.

Examples of how the stage and the staging of a modern drama works, both semiotically and hermeneutically, can be found in the richness of form and variety of expression in set design and acting. In the famous and absurd avant-garde play *Waiting for Godot* (Becket, 1956) the characters Estragon and Vladimir are waiting on a country road by a tree. On the stage there is a tree, often a moon, and possibly some other props; Estragon's boots and Vladimir's hat also play important parts in this play. The tree in the set design may be a fully naturalistic model of a tree, an abstract sculpture of a tree (Fig. 36), a pole, a shadow of a tree displayed by light gobos or projections (Fig. 37), one of the actors showing or acting a tree, the word "tree" as text written on a sign or on the floor, like in the movie *Dogville* (Fig. 38), or just that the audience is told that there is a tree. Semiotically speaking, all of these are plausible signifiers of the concept of tree in the play. Even the absence of a tree is a signifier for a tree in the code of theatre. The play itself concerns questions like the existence of, and lacking, meaning and things. This theme of the play strengthens the code and produces sign relations, where the arbitrary representation of the tree links strongly to the chain of signs.

Figure 36. Waiting for Godot (Chris Honer, 2008)

Figure 37. Waiting for Godot (Kathryn Moller, 2007)

Figure 38. Dogville (Lars von Trier, 2003)

We can note that, in this space, the actual representation of the tree can be chosen freely as long as there is an established agreement within the space. From a hermeneutic point of view, the interpretation of the tree works in this space in relation to the expectations, agreements and experiences that are made. The stage works as an arena for these relations in the way that Ricoeur describes. Firstly in the arrangement or composition of sets, actors, and lines that form the text, then in the genre that the director, the actors, the set designer, and the audience have agreed upon in relation to the world of theatre (that creates expectations), and lastly in the experience of the specific style of this particular work of art. Altogether, the Stage works as a space for understanding, a "seeing place".

Staging the Drama

The word drama comes from the Greek word for action and constitutes the concept for what classical theatre is. It is difficult to define *stage* without relating to a place for drama, leading back to Aristotle's statements about lyric and drama (Aristotle 1450b). The early examples of classical theatre in Athens were comedies and tragedies that attracted thousands of spectators and played an important part in society, both socially and politically. According to Aristotle the major goal of theatre was to release emotions and insights about the world through the experience of fiction, and thus the drama had to be relevant and believable to the audience. Illusion is a central concept in classical drama, but not for its own sake but rather with the purpose of creating emotions that can lead to understanding of real life. Meaning was created in this process of illusion leading to emotions leading to understanding.

The drama in classical theatre is based on literature and then transformed into a format that works in the defined concept of actors reading the script on a proscenium in front of a set, facing an auditorium with spectators. The structure of the drama, known as dramaturgy, was well calculated and followed more or less standard formats. The most well-known is the pyramid graph that describes the format of ancient Greek tragedy, with rising action up to a climax point halfway and then a falling action that leads down to the final catastrophe (Fig. 39).

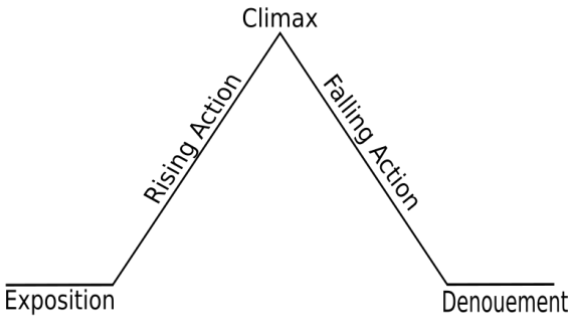


Figure 39. Freytag's triangular Pyramid graph (public domain)

Aristotle stated that all dramatic stories have a "beginning and middle and end" (Aristotle 1450b, translated 1932), which might seem obvious, but this view has been a structural concept of all dramatic stories of classical theatre. The order of events needs to be consecutive and flashbacks, parallel stories or open endings do not belong to this way of staging a story. Shakespeare's tragedies have also been used as a model for this way of forming a drama in rising, climax, and falling, as for example in *Romeo and Juliet* from 1595-96. This progression of rising and falling action is a founding concept for the classical drama.

An important heritage from the ancient Greek drama is also "the three units" (*translated from: de tre enheterna*), stating that a play should be consistent in space (in one place), time (in one day), and drama (following one story). Many of our later playwrights have adopted this concept, like Strindberg (*Fadren*, 1887) and Sartre (*Morts sans sepulture*, 1946). This way of setting the play in one confined place in real-time creates an intense drama where neither the actors nor the audience can escape from the inevitable final catastrophe.

In the 20th century, the film industry of Hollywood adapted the classical structure of drama and developed it further to work better in the film medium. The "Hollywood model" introduced the "point of no return" leading to the climax and placed this climax closer in time to the end of the story, in order to leave more time for the conflict escalation and less for the final resolution. The Hollywood film industry might have focused more on happy than tragic endings but the general idea about how to tell a story was the same as in classical theatre. With the dominance of this structure of drama in both theatre and film, other ways of telling stories are still seen as alternatives to the norm.

In modern theatre, these standard models have been challenged. Throughout the 20th century there have been many contributions to new forms of theatre, mainly in Europe. These movements are known as avant-garde, experimental, or performance theatre. They had an innovative and experimental approach and introduced new concepts, methods and representations. An early conceptual statement was that theatre should be less artificial. The drama should take place in real life and concern directly with real life situations. This was achieved by introducing new methods in rehearsing with the actors, re-inventing the theatrical spoken word and body language, and introducing new technology. An important method was also to work with the space for theatre not as divided in stage vs. auditorium but as unified for both actors and spectators. The performances could be staged in non-traditional places such as streets, squares, or public buildings. All of this resulted in new representations that were innovative in acting, storytelling and technological use. The focus was no longer on evoking emotions through an illusion, but rather on supporting an intellectual process by different sensorial stimuli. In the avant-garde form of theatre, meaning is created in physical (sometimes direct) and intellectual (often shocking or confusing) interaction with the audience leading to experiences leading to an intellectual process. This form of performance requires more effort from both the actors' and the spectators' part than just acting and looking. The avant-garde movements reinvented the agreements that are made in staging a drama.

One early milestone was when in 1897 the Russian actor Constantin Stanislavski opened the Moscow Art Theatre (MAT). This theatre was based on new ideas about realism, the actors' process, how the play was staged, and public accessory to theatre. As such the MAT also played an important part of the transformation of cultural life from the Russian to the Soviet era. Stanislavski used the theatre and its technical possibilities as an instrument of expression, a language, in its own right. He believed in theatre as a unique medium and form of art, not just as a means of reading text out loud in front of a (privileged) audience. The meaning was created in the staging itself. Stanislavski worked with the play using a different method, not relying on the text as much or providing literary explanations, but rather working with the dynamics and the actions and the thoughts and feelings of the characters. In his performances there was a constant flow of action. The staging of Anton Chekhov's *The Seagull* in 1898 has been described as "one of the greatest new developments in the history of world

drama" (Benedetti, 1989). He focused on the *subtext* rather than the actual lines of text, which gave the drama a completely new psychological depth and dimension. In rehearsal Stanislavski worked with the actors using "score cards" where he described in detail each character's actions and making the actors "live the role" as it has been described in his own *An actor prepares* (Stanislavski, 1936). He introduced in the 1920's the concept "if" to reinvent the process of creation in theatre (Milling & Ley, 2001). The central problem of performance for Stanislavski was that of acting in a play in a theatre in front of an audience, and that problem formed the core of his theoretical system (Stanislavski, 1977). Stanislavski's most important theoretical works are *An Actor Prepares* (1936), *Building a Character* (1949) and *Creating a Role* (1961). These publications deal mainly with the process of the actor and the director, but also involve the relations between the actor, the stage and the audience. His central concept about acting "if" relates not only to the development of an actor's character but also to the stage as a space for storytelling and interaction.

The German playwright and theatre director Bertolt Brecht developed these modern ideas further into what he called "epic theatre", where theatre is a forum for political (Marxist) ideas and for critical aesthetics (Brecht, 1950). Epic theatre proposed that a play should not cause the spectator to identify emotionally with the drama but should instead provoke rational self-reflection and a critical view of the action on the stage. Brecht thought that the classical drama, based on emotional connections, just left the audience content and passive. Instead, he wanted his audience to adopt a critical perspective in order to recognise social injustice and to be inspired to go on from the theatre and make changes in the real world. For this purpose, Brecht used techniques that reminded the spectator that the play is a *representation of reality* and not reality itself. This form of metatheatre includes self-reference of the drama and play within the play, so that the agreements between the actors, the drama, the stage, and the spectators are constantly challenged and re-invented. By highlighting the constructed nature of the theatrical event, Brecht wanted to communicate that the audience's reality was equally constructed and changeable.

After Stanislavski and Brecht, a second era of experimental theatre evolved in Europe in the 50's and 60's. The pioneers of this period focused on the interaction between actors and spectators and on theatre as a ritual or ceremony. The influential British playwright and director Peter Brook envisioned "…a necessary theatre, one in which there is only a practical difference between actor and audience, not a fundamental one" (Brook, 1968). In his view, theatre should be based on continuous interplay between actors and spectators. Brook also coined the term "Art as Vehicle", showing that another level of perception could be accessed in the art of performance. Experimental theatre of this time worked with the act as a ritual, a ceremonial circle during performance, the actors providing one half, the audience providing another, and the energy in the middle. Here the stage played an important part as the spatial center point of this energy. The Polish director Jerzy Grotowski is considered as one of the main innovators of experimental theatre. In his book *Towards a Poor Theatre* (Grotowski, 1968) it is declared that theatre should not, and could not, compete against the overwhelming spectacle of film and should instead focus on the fundamental qualities of live performance: actors co-creating the event of theatre with its spectators. He went to far eastern countries to study ancient ceremonies searching for the roots of the act of theatre. Grotowski wrote that "Theatre - through the actor's technique, his art in which the living organism strives for higher motives - provides an opportunity for what could be called integration, the discarding of masks, the revealing of the real substance: a totality of physical and mental reactions. It is true that the actor accomplishes this act, but he can only do so through an encounter with the spectator - intimately, visibly, not hiding behind a cameraman, wardrobe mistress, stage designer or make-up girl - in direct confrontation with him, and somehow instead of him. The actor's act - discarding half measures, revealing, opening up, emerging from himself as opposed to closing

up - is an invitation to the spectator" (Grotowski, 1968). This act Grotowski called a "total act", meaning that this was the true calling of theatre.

As a theoretical contribution, the works of these playwrights and directors created a fundamentally new paradigm of performing arts. It is obvious that these modern ideas were not isolated to theatre but appearing simultaneously in other fields of knowledge. Similarities can be seen in the development of visual art, architecture, and literature. For example, cubist works by Picasso and modernist architecture by Le Corbusier challenged classical aesthetics and concepts. Philosophers of the 20th century also introduced new ideas that questioned the established models of interpretation, experience, understanding and aesthetics. This can be seen as a parallel process to the practice-based contributions of the avant-garde pioneers in performing arts developing theatre as idea, method and practice. Hans-Georg Gadamer challenged, in his famous *Truth and Method* (Gadamer, 1960), both the scientific models of human sciences and also the idea that true understanding (of a text) could only be achieved by having full knowledge of the author's intentions. He claimed that the meaning of a text (or work of art) is dependent on the context of interpretation. Gadamer's concept about play (German *Spiel*) concerns the ontology of art, where the play is not the object but rather the subject independent of the actors involved. Play is what is happening between all actors involved (including spectators) and the play appears as truth when the play is underway. According to Gadamer, the importance of art lies not in the work of art itself but in the process of parallel transformation and communication where the viewer becomes the actor and participator. This idea is coherent with the more popularly known concept of the "death of the author", coined by Roland Barthes and used as the title of his famous essay (Barthes, 1977). Gadamer's idea shows that the meaning of staging a drama lies in the interplay between the experiences of the audience and the actual performance, not in the intended message of the author or director. True meaning appears only on stage and only during the performance.

In film, a lot of experimental work was also done that challenged the norm of dramaturgy. Early works, as for example the surrealist *Un Chien Andalou* (*An Andalucian Dog*, Dalí, Bunuel, 1929) showed that the film as medium had much more to offer than the traditional structure of drama. Later innovative filmmakers, like Lars von Trier and Thomas Vinterberg, has proved that new forms of staging the drama can be made by adding constraints to the artistic process. In their *Dogme 95 Manifesto* (Utterson, 2005) rules were set that forced the use of handheld cameras and restricted the filmmaker from using lights, sets or special effects. The manifesto also stated that "the director must not be credited", which directly can be referred to "the death of the author".

With the rise of new media such as the Internet and computer games in the late 20th century, new ways of structuring stories were made possible. Opening up the narrative to interaction with the audience (the users) the order of events did no longer have to be consecutive as in a film or classical theatre play. New technology has led to new ways of staging the drama. For example, using mobile phones in pervasive gaming[37] makes it possible to stage a virtual game in the real world. In interactive storytelling users create or influence a dramatic storyline through actions, either by giving commands to the characters or acting as a director of events in the narrative. Interactive storytelling is a medium where the narrative and its evolution can be influenced in real-time by a user. However, this openness and possibility of interaction does not affect the fact that all events happen in a consecutive sequence, once the choices have been made.

[37] A game where the gaming experience is extended out in the real world, or where the fictive world in which the game takes place blends with the physical world.

In summary, a stage is a complex place that conceptually includes a wide range of aspects. The theatre stage is a place for seeing, looking at, making agreements, acting, feeling, meeting, interacting, transforming, showing, and telling stories. It can have many appearances and forms in material and scale. Décor and props can be physical or virtual; it does not matter since the meaning on stage is created through perception that disregards materiality. The organisational structure can also vary, so that the stage is peripheral or central in relation to other connected spaces. However, the stage is the focus of attention, making it highlighted for the viewers and actors regarding gaze, hearing, touch and other senses. On stage, looking at the stage, and interacting with the stage, are the actors and audience, which respective roles can be altered and configurated in a variety of combinations. Behind the stage, there is a machinery that supplies and supports the stage and the staged events with items, lights, props, sounds, fire, smoke etc. And there is the drama, the spoken and written words that form lines that form scenes, acts, and the play.

Stage: A place for agreement, attention, and experience, where people have different roles, interacting with physical and virtual spaces.

Virtual Space as Stage

"Almost Real"

Virtual environments are constantly compared with reality, where the question is: Does it look and feel real? Different studies (Hoffman, 1998; Meijer et al., 2009; Slater, 2009) show that visual realism is an important factor for the sense of "being there" in a VE. The more photo-realistic a visual display is the higher presence in the VE is reported from the test subjects. Even quantitative data in the form of skin conductance and heart rate has been used to prove this point. Also realism in auditory and haptic feedback improves presence. Other studies (Sadowski & Stanney, 2002; Youngblut & Huie, 2003) then show that task performance in a VE is related to presence, so that the higher presence the higher task performance. Social factors are also studied (Slater et al., 2000) in order to compare collaboration in group work with face to face situations. The basic idea of these studies is that the real world is the ideal model that virtual environments need to come as close as possible to in order to work properly. Higher screen resolution, better colour reproduction, smoother edges and higher frame rate are the measurements for realism. The examples that are used are mainly architectural visualizations, real-like landscapes or settings with ordinary objects like chairs, building blocks and poster signs.

In these types of research projects I have been involved in, like the Cube Puzzle project, the settings are very similar to a theatre stage. The space is confined like in a play of Jean-Paul Sartre with a set of rules and a task that drives the story forward. The users enter the space with some sort of introduction that works as the base for the agreement between the user and the environment, or put differently, between the actor and the space. Before the user puts on the VR display or steps into the VR Cube, the user is given instructions what to do, what to expect and also what the environment shows. Then the curtain opens and the play begins. In these VE's there is a crossover in roles so that the spectator also can be the actor (Ljungar-Chapelon, 2008), which creates a different experience than seeing or acting in a theatre play. Nevertheless, the virtual space works as a stage where both reality and virtuality are studied through real-like models and examples. The VE becomes a realistic model of a part of reality. This approach to create a subset of the real world on stage, where real world conditions are represented more clearly and condensed, is one of the founding concepts of theatre all the way

from Greek tragedy to modern drama. Throughout history, theatre has been an important forum for displaying and debating different views on society (Holm, 1969). German author Berthold Brecht is the most famous example of a playwright that used the theatre stage as a means of expressing political views. His work shows that by creating a space of "almost real" much can be said about reality.

"More than Real"

Another aspect of virtual environments is that they can show phenomena that cannot be seen in real life. The user can see, hear or touch molecular structures, temperature, air pressure or black holes in different scientific or entertainment visualizations. In science centers visitors use VE's that let them travel through space and time in order to experience other galaxies or live dinosaurs. Here the VE works as an augmentation of the user's body in a way that can be compared to "superpowers". In the studies of the *Virtual Molecules* project that I worked on (A.-S. Axelsson et al., 1999) it was shown that users felt present in the VE even though the environment was not realistic, neither in sound nor vision. The balls, sticks, spirals and organic shapes of the molecular models worked as metonyms for their physical equivalents and created a rhetorical space where users could interact and feel present.

In artistic VE's users experience imaginary spaces that expand other art forms like performance, theatre, video, dance etc. Early work like *Osmose* (Davies, 1995) or more recent work (Ljungar-Chapelon, 2008) show that such VE's are crossovers of different art forms and computer games, that open up unique ways of artistic expressions. In these Virtual Reality "arts plays" metaphors become important since they have the ability to link former knowledge from the world outside with the new experience inside the VE. A virtual language takes form based on the semiotics of these metaphors, and the VE becomes a world of its own with its own set of rules.

This relationship between real and virtual is also coherent with the theatre stage. In non-traditional or experimental theatre alternative and new (sometimes provocative) agreements need to be made between audience, actors and space. Ground-breaking work was made by Polish director Jerzy Grotowski in the 1950's and 60's that influenced later artists (Milling & Ley, 2001). He worked with the theatre as a ritual, where almost any agreement was possible, making the stage a place for something "more than real". His performances created a new language for theatre; actors replacing props and furniture, the audience placed around a table with the actors on top, or the stage built around the audience are examples of his settings (Wolford & Schechner, 2001). The sets did not depend on visual resemblance to the real world, but rather on meaningful representations. This approach has formed a style of its own and lives on today in contemporary performing arts.

"As If"

Virtual Reality simulates reality. There are virtual simulations of driving cars, flying airplanes, repairing nuclear plants, making surgery and making war. The main reason for creating these simulations is to replace training activities that are unreasonably expensive or dangerous to practice in the real world. The purpose is pedagogical or presentational. Here visual realism in the VE is important to create for a close relation between real and virtual. At the same time, additional information is put into the virtual simulation, such as text, arrows and other graphics, in order to enhance the VE or make up for limitations of the VE. However, the idea is not to copy the real-world situation, but to simulate. Simulating something requires a model that represents the characteristics of the physical system. The model represents the system itself, whereas the simulation represents the operation of the system over time (Sherman & Craig, 2003). The philosophical aspect of simulation lies in the notion of "as if". A user experiences and acts in the VE simulation as if it were the physical system. However, the user does not believe that he or she is actually using the physical system but needs to agree on that

the VE simulation represents or replaces the physical system for a certain purpose. Here metonyms (the substitution of signifiers based on understood association) come into play in order to create a meaningful language for the user in the VE simulation. Objects and relations of the physical system are substituted by virtual objects so that the user, in the interaction with the VE simulation over time, appreciates the virtual system as if it were the physical system.

The creation of a meaningful language on a theatre stage can be seen in the same way, the stage being the model and the performance of the play being the simulation of a system in the real world. Stanislavski introduced in the 1920's the concept "if" to redescribe the process of creation in theatre (Milling & Ley, 2001). The central problem of performance for Stanislavski was that of acting in a play in a theatre in front of an audience, and that problem formed the core of his theoretical system. His publications deal mainly with the process of the actor and the director, but involve also the relations between the actor, the stage and the audience. His central concept about acting "if" relates not only to the development of an actor's character but also to the stage as a space for storytelling and interaction. Stanislavski does not state "We are in 17th century Denmark" but "If we were in 17th century Denmark, then…" and this approach opens up the negotiation between performance and audience to form new agreements. Theoretically, this idea connects well with contemporary virtual environments. Stanislavski's founding ideas to both work into the space of the actor and the play and also outside across the boundaries of the stage are parallel to the metaphors of virtual space. The ruling metaphor for virtual space is that the actor steps into another world, while cyberspace is a space for exploring and reaching out to the unknown. The computer screen, as well as the stage proscenium, is both a window into another space, but also a means of travelling to other destinations.

Connecting Stage with Physical-Virtual Space

Using Stage as metaphor emphasizes *agreement*, *attention* and *experience* as central concepts. Firstly, agreements on the illusion and the construction of the performance. In classical theatre, the performance creates an illusion of reality that leads to emotions that tell us about the real world. In modern theatre, the performance shows a constructed or distorted reality that leads to an intellectual process aiming at understanding and changing the real world. Secondly, attention to the common shared space of actors and spectators. In all theatre, the founding condition is co-presence of the actors and the spectators in a shared space, where the interaction is constantly explored and developed, both in theory and practice. These concepts of agreement, attention and experience are also founding concepts of virtual space, showing that there are strong and meaningful relations between stage and virtual space.

Just like in theatre, virtual space is an abstract yet immersive space for interactions and experience, where interactions take place in a shared physical-virtual space. Site-specific theatre, like the classical amphitheatre and modern staging in actual sites, is essentially a physical-virtual interaction space, where the actual physical space constitutes the context for the virtual. Physical-virtual space becomes an immersive theatre, *A Seeing Place*. As in theatre, this place is for seeing what was, what is, and what can be.

A Seeing Place: A unifying concept for Stage, Virtual Space, Physical Space, and Actor[38]

[38] Actor, in the sense of active user, not only as in theatre role play actor.

5. Cases

In the following cases I exemplify and discuss how a physical-virtual space can be analysed and understood as a stage, a seeing place. The idea is to look at real-life situations, where physical and virtual space co-exist in the sense of spatial perception. In some examples virtual space function as an extension of physical space, with the purpose of enabling functions or giving experiences that cannot be realised in physical space. In other of these cases physical and virtual space are more mutually interdependent, where connections between spaces are made through human interaction. The stage metaphor is used as a unifying concept to connect the agreements and experiences to both physical and virtual space.

The seven cases investigate different contexts for the research questions. The aim is to explore, describe, and explain the central ideas of the research in a number of illustrative situations. The purpose of the cases is to test the theoretical framework and methods, demonstrating the possibilities and limitations of the models.

The following seven cases are presented:

1. Block-Box-Prism-Wedge (2005-2008)
   Creating a common place for physical and virtual space in architectural design
2. Physical and Virtual spaces for Art (2007)
   Investigating relations between physical and virtual museums and art galleries
3. Baltic Sea Forum (2008)
   Developing a design concept for a science center based on the surface metaphor
4. Museum of Natural History (2009/2019)
   Seeing the potential of virtual space as overlaying physical space in a museum
5. Emergency Response Center (2010)
   Exploring a physical-virtual space for decision-making as a stage
6. Virtual Culture House (2012-2014)
   Staging the interaction with citizens in physical-virtual spaces for urban planning
7. Interactive Science Center (2016-2019)
   Creating a common place for physical and virtual space in a science center

CASE 1: BLOCK-BOX-PRISM-WEDGE

This case explores RQ1 on the levels of design, philosophy of design, and semiotics. The investigation consists of practical design, reflection, and theoretical reasoning. This case also explores RQ2 in the investigation of how metaphor can contribute to the connection between physical and virtual space. RQ3, how can a common place for the physical and virtual be formed in the practice of design, is the main focus in this case.

The Interplay Between Physical and Virtual Spaces in Architectural Concepts

The architectural design process is a complex method that involves aesthetic, technological, economic and social issues. The process is, to a varied extent, tried against regulations, clients' demands, material limitations and new ideas of the architects. One architect or group of architects can also manage a number of projects simultaneously that influence each other so that conditions, ideas and requirements in one project affect the design process in another. Virtual representations in the form of CAD spaces, rendered 3-D models and digitally manipulated images are shared in order to communicate the architectural design. The purpose might be artistic, social or commercial in relation to the target group of the communication.

The increased use of virtual models and images in the design process opens up a transfer of knowledge between physical and virtual architecture (Milovanovic et al., 2017). In the following example I focus on four architectural design concepts and investigate the connotations of these designs together with an analysis of the transfer and interplay between physical and virtual representations. In order to explain the concepts, the creative environment and background are introduced.

Creative Environment

Arctic Studio was founded in Göteborg in 2001 as a cross-disciplinary studio for digital media and architecture.[39] After four years of smaller projects in visualization, private housing and interior design, the studio was established in a physical space with the ambition to combine architectural projects with a gallery for visual art.[40] The studio became not only an architecture office but also a social and artistic arena for artists, designers and architects that could interact with a public audience. All the projects in the following examples have been designed by me (or by me in collaboration with others) at Arctic Studio, if not noted otherwise.

Since 1998 I have also been employed at Chalmers University of Technology, starting as a VR developer at Chalmers Medialab[41], the creative melting-pot for digital media. From 2001 until 2004 I worked as a project manager for VR and visualization, mainly occupied with research projects in the Chalmers VR-CUBE. Since 2004 I have been employed at Applied IT and then Computer Science and Engineering as a teacher and researcher in visualization and interaction design.

Phase 1: Realisation of Architectural Projects 2006 - 2008

In the period from 2006 until 2008, Arctic Studio realised four site-specific private houses that became the origin of the four architectural concepts that will be presented in three phases in

[39] Founded by Fredrik Ludvigsson (designer and architect), Andreas d'Arienzo (building engineer), and Josef Wideström (architect, visualization expert and stage designer). d'Arienzo left the studio in 2002, while Ludvigsson remained loosely connected to the studio until 2006.

[40] Established by Björn Gross (architect) and Josef Wideström in 2005, with office and art gallery at Sveagatan as the meeting-point for the activities. In 2008 Arctic Studio moved another location.

[41] Chalmers Medialab was founded in 1997 on a substantial donation from Volvo, together with SGI and Oracle. Its mission was to implement digital media, theoretically as well as practically, in research and education at Chalmers.

this case. The conceptual shapes, explained further in phases 2-3, are named Block, Box, Prism and Wedge. When looking at the realised projects below, it might appear as if one project is only linked to one of the conceptual shapes. Later, the analysis will show that each of the concepts is extracted from all four houses.

Villa Tetris, Solbacka, 2006

Figure 40. Landscape, exterior, and interior of Villa Tetris (Gross, Wideström, 2006)

We designed this private house for a disabled 60-year-old writer that moved out from the city for the peace and quiet of the countryside. The Wedge-shaped building adapts to the topography and directions of the landscape, and the interior floor is levelled with the exterior so that a minimum of obstacles is achieved (Fig. 40). The shape originates from a Tetris puzzle concept, where two L-shaped volumes frame an open yet transparent interior living space. The transparency, together with the elaborate adaptation to the landscape, creates interplay between interior and exterior space.
Using Peirce's triad and sign process to analyse the architecture results as follows:
(O=object, S=sign and I=interpretant)

1. O: Wedge-like building, S: Flat shape with sloping roof, I: The building fits into the landscape
2. O: Integration with the landscape, S: Transparency through the building, I: Exterior space is integrated with the interior
3. O: Integration of interior and exterior space, S: A rock wall outside the glass, I: The rock wall outside is an interior wall

The analyses above must be seen as one of many possible sign processes in the interpretation of this work. It can be noted that if, for example, the object connected with sign number one is "knife" rather than "wedge" and its interpretant is "cuts the landscape" then the whole interpretation of the design might be altered from "integration" to "separation". Apart from transparency and the Wedge shape the architectural gestalt contains an almost endless set of signs, of which some support and some contradict each other in relation to the general idea of the building. Just to point out a few of the most important, it can be said that the whole wooden cover of the structure has the characteristic of a Box and that the two L-shaped Tetris pieces are basically Blocks. Similar analyses were performed on the following three realised buildings, altogether forming a code for our architecture. The concepts of each project are here presented in photographs together with a brief description.

Villa Viti, Fjällbacka, 2006

Figure 41. Landscape, exterior, and interior of Villa Viti (Gross, Mäki, 2006). Photo: K. Engström

This project deals with the landscape in a different way, overlooking the sea to the west and opening up to the sunlight from the south, with diagonal cuts that create a rhombic plan (Fig. 41). The precise Prism-shaped volume is cut open in the glazed corners over wall-to-wall or wall-to-roof. The site was strictly regulated in terms of building measures, materials and colours, which lead to this modern version of a traditional west-coast private house.[42]

Villa Wiwa, Onsala, 2007

Figure 42. Landscape, exterior, and interior of Villa Wiwa (Wideström, 2007)

Designed for one person, this house has a lot of open interior space, while the exterior is more closed, like a Block (Fig. 42). The composition of windows and doors is a playful yet strictly regulated game, using a combination of only two types of openings – 9x21 dm and 9x6 dm.

Villa Cliffhanger, Aspenäs, 2008

Figure 43. Landscape, exterior, and interior of Cliffhanger (Gross, Wideström, 2008). Photo: K. Engström

This building is situated on an extreme rock hillside, so that the back of the house is mainly underground while the front side rises up on pillars (Fig. 43). It has a solid concrete base that adapts to the topography and on top of that a wooden Box with openings cut out. A diagonal roof ridge gives all four facades of the building a sloping upper side, making the Box more dynamic.

Phase 2: Conceptualisation into Virtual Models, 2007

From the experience of working with these projects, building on the emerging code, we pursued with conceptualisation of the architecture. In this process, we started making virtual representations (3-D models) of our projects. It was during the design process of the Cliffhanger project in 2007 that we started comparing the physical buildings and the virtual models in order to identify common ideas. At that time we also had a number of our other own projects running that all had different conditions but showed similar expressions in their virtual representations, only in new combinations. It became clear that knowledge was transferring from the physical to the virtual representations. These virtual representations contained knowledge and experience of the realised projects, while they also created expectations and were a source of knowledge for the ongoing and future projects.

As a result of this design work and reflection, four basic conceptual shapes started to take form. They emerged from analyses of the design process separated under three headlines:

[42] In cooperation with Jenny Mäki. This project was also the master thesis work in architecture by Björn Gross and Jenny Mäki at Chalmers in 2005.

idea, method and representation. In each project, conceptual shapes had been created from the conditions of the project, then elaborated and developed through the method of virtualization as a space for the acts of communication, and then realised as a materialization of these ideas and methods. These representations then formed new ideas and influenced other ongoing processes, so that a code emerged. This code can be seen as a space. The following presentation of the four concepts shows how we extracted architectural concepts from this space.

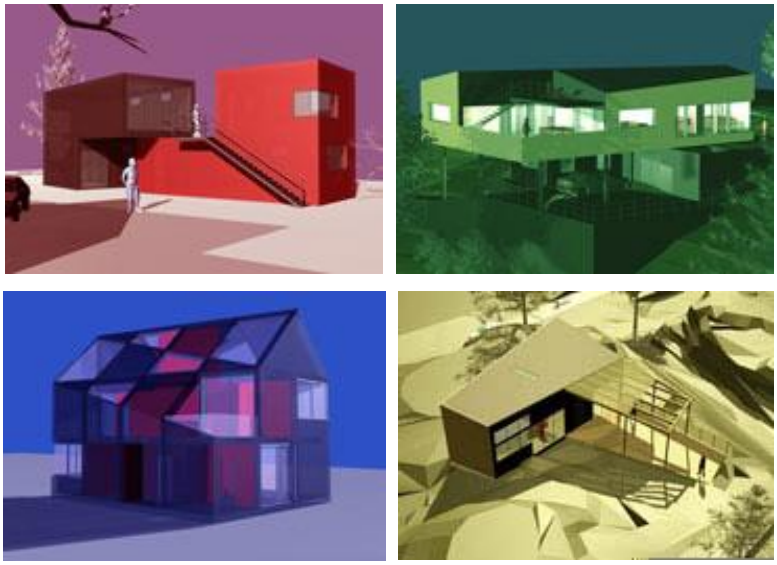


Figure 44. Design concepts for Block, Box, Prism, Wedge (Gross, Wideström, 2007)

These renders of the virtual 3-D models (Fig. 44) were presented in an exhibition at Arctic Studio in February 2007. Around 200 people visited the exhibition at the studio and around 800 people visited the exhibition web site during February and March. Informal comments on the concepts from the audience were collected in both written and spoken form (not presented here). One aspect we noted is that not many people we concerned whether the concepts were intended as physical buildings or not. The experience of this virtual architecture seemed to be the most important quality for the audience. The actual situation was that only the Box had a physical representation, in the Cliffhanger project (finished in June 2008). The Wedge was realised in 2009 but in a completely different form, the Block was started as a proposal for two artists' studios but continued as our own development project, and the Prism was originally a development project without any connection to client demands.

Phase 3: Development of the Four Design Concepts, 2008

The next phase was to refine the design concepts further and to give them new life, aside from the conditions of specific project demands, like grains of space extracted from the code. In order to turn the conventional process in architectural design around, the implication context → program → material → shape was reversed so that the shapes became the starting point of the process. The conceptual origin of these shapes was the result of the extractions made in phase 2. What should then the spatial origin of these shapes be? It could be a point, a line, a sphere or any other Euclidian entity or array. The choice fell on the Cube. With a measure of 12 meters, the Cube constituted a base for human scale architectural spaces. In each of the four design concepts, the cube was then transformed using rules for the impact on the cube, like a game between idea, method and representation. A common rule in all cases was that no geometry was to be removed or added, only transformed. The aim in all design concepts was to create interior space with daylight on every of the 3-meter-high floor levels. Here follows a presentation of the idea, method and representation of each conceptual shape (Table 1).

Design Concept	Idea / Connotation	Method / Rule of transformation	Representation / Shape
Block	massive, closed, heavy, secure, impenetrable, solid	The Cube must repeat itself in the parts where the impact is made	Perpendicular, a combination of L-shapes and squares, close to the original Cube
Box	embracing, secretive, semi-open, flexible open/closed, dualistic	Separate inside and outside, use principle of half-and-half for every change of the Cube	A 1⁄2-transparent shell and a 1⁄2-transparent core, a rectangular composition of 1x1, 1x2 and 1x4
Prism	reflecting, interfering, sharp, transparent, optimistic	Only diagonal cuts of the Cube, and only in all three dimensions	Triangular and rhombic shapes, pointed angles
Wedge	dynamic, integrated, confident, threatening, promising	Stretch and skew the Cube, with the condition of keeping the volume constant	Trapezoid shapes in two dimensions and rectangular shapes in the third

Table 1 - The interplay between idea, method and representation (Gross, Wideström, 2008)

In order to follow the process of creation in the table above, it should not be read row by row from left to right, but rather in any order. All four concepts were created simultaneously, with a constant development of connotations, rules and shapes. The rules were not only followed but also created in this game of sign production.

Addressing RQ2 on the higher level of abstraction, the four design concepts are metaphors for the ideas, taking form in a Block, a Box, a Prism, and a Wedge. These ideas are the *sense* of the metaphor, creatively transforming the language of architecture, in the line of Ricoeur's analysis. They are essentially "productions of discourse as a work", with the arrangement as described in Table 1, in the genre of architecture, and with the particular style of Arctic Studio. As metaphors, they support conceptualization and implementation of the relations between physical and virtual Space.

Four different materials were then integrated into the four concepts, with a choice of materials based on idea, method and representation. Block became concrete, Box wood, Prism glass, and Wedge metal. The intention was to make also the materials work as metaphor for the connotations in each design concept. The shapes had now become metaphorical buildings. In order to give the concepts gestalt in this phase, we built physical models in the scale 1:100 (Fig. 45). The materiality of these representations gave the design concepts new dimension. They are "physical" and "real" in the sense of being tangible and constituted of atoms rather than bits, but "virtual" in the sense of not being actual buildings that still could be perceived and experienced.

Figure 45. Physical models of Block, Box, Prism, Wedge, with materials (Gross, Wideström, 2008)

Phase 4: Staging the Four Design Concepts, 2008

Taking step by step in this reversed design process shape → material → program → context, it was time to find a program for the buildings and to introduce them in a context. In June 2008, Arctic Studio was about to move to Klippan area in Göteborg, so it was natural to choose the waterside at Klippan as the site. The area was photographed, the concepts rendered in 3-D models and then integrated into the 2-D photo images using compositing with digital manipulation of both the renderings and the photographs. The intention with the visual style was to show a kind of uncertainty – not too realistic and not too unrealistic. The physical models of the buildings (Fig. 45) are deliberately a little too abstract to be seen as realistic, while the 3-D renderings (Fig. 46) integrated in the site (shadows, reflections in the water in Block and Box, environmental reflections on the buildings in Prism and Wedge, over-exposure on both the stones and the façade in Prism, etc.) have a more realistic appearance. The idea was to communicate the impression of real-world presence of virtual architecture – interplay between reality and virtuality.

Figure 46. 3-D renderings of Block, Box, Prism, Wedge (Gross, Wideström, 2008)

These design concepts were presented in May 2008 as the final exhibition before the studio moved to Klippan. Again, around 200 people saw the exhibition at the studio and around 800 visited the web site during the exhibition period. In addition to this attention, the concepts were published with a full centerfold article in the *Göteborg Direktpress* local paper magazine and with a brief article on the *Business Region Göteborg ADA* web site for design marketing, both of these media having thousands of readers and viewers. With this wide spread of the four design concepts, many people were able to experience these grains of architectural space and, through them, the traces of the whole sign process. The context for these images, when published, was to show plans for future projects. Direktpress wrote in the article that:

> *"Under four architectural themes: the wedge (metal), the block (concrete), the prism (glass), and the box (wood), the intention is to show different solutions for schools, apartments and offices, to which Klippan has been the model. Exciting and innovative; artistic values have been integrated in the function." (translated from Swedish)*
>
> Madeleine Christell, Frölunda Majorna Direktpress Göteborg, p. 14-15, 2008-06-15

These media publications created expectations and an awareness of coming changes in the physical urban space. The images were planted in the public conscience as architectural space. Rumours started that something was going on and ideas about how to support or oppose to these plans were formed. The virtual architectural concepts formed a production of real social space.

Addressing RQ2 and RQ3 on the lower levels of abstraction, the whole design process of prototyping in different media, testing in public exhibitions, and evaluating through analysis, has formed a 'stage' for supporting the connections between physical and virtual spaces. The use of this 'stage' has been deliberate in this project as a way to connect physical and virtual spaces through the interactions of a variety of users/actors. Physical and virtual space cannot interconnect by themselves, only by human interactions. The actors on the stage of this architectural design process are of course us as architects (taking the leading role in this drama), the clients of the projects (actors contributing with human needs), municipality and other decision makers (context-providing antagonists), visitors to the exhibitions (audience), and media (turning on the spotlights). The architecture itself, with its physical and virtual elements, has formed the structure and the material content as décor and props on the stage. As always in a theatre, the 'real' work is done behind the scenes, from engineers and craftsmen that build the physical constructions to the programmers and developers of the digital tools.

Semiotics of Physical-Virtual Space

Architecture, regarded as the design of spatial systems, and semiotics, as the study of sign process of semiosis, are conceptually related. Both disciplines deal with language in a wider sense. The production of space is also a production of signs. Like architecture, semiotics relies on the interplay between expectation, agreement and experience of an agent/observer.

Addressing RQ1 on level III, the case of the four design concepts shows that the code, the space, is ever changing and in motion. As Derrida explains, the interpretation itself leaves traces that affect the sign process in a game that constantly leads to new interpretations. As soon as these design concepts were developed, they were not only extractions from the code but also changed the code. Though being virtual architecture, they made real impact in the physical world. They contributed not only in relation to social space as described above, but also as new spaces of reference for the development of our following architectural projects.

In the interaction between physical and virtual spaces new signs emerge. They can be categorised into three systems; signs from physical space in virtual space, signs from virtual space in physical space, and physical-virtual signs. The first two systems contain signs that are reused in new contexts, and given new meaning, so that the signifier is connected to another signified. Illustrated in a simple example, the use of folders and files in digital applications comes from interaction with real-life folders and files. A folder in a virtual environment is now a sign (icon) that stands for something else than what can be done with a real-life folder. The physical-virtual signs indicate the coexistence and cooperation of physical and virtual space, like the architectural concepts extracted from the physical-virtual sign process in this case. These signs are not well-known words in new contexts but form a new language. The formation of this language means that the language not only speaks us, but that we speak a new language. From a deconstruction point of view, the meaning of these physical-virtual signs lies in the game that emerges and what other concepts and signifiers that are triggered. In order to develop this language further, more shapes have been created from each concept. In this work, the code that emerged from the four design concepts have resulted in more examples of architecture in the line of these ideas.[43]

[43] More projects can be found at http://arcticstudio.se

Relations Between Physical and Virtual Space

Physical spaces and virtual spaces are different in character. They are spaces, both in a semiotic sense as a code and from a perceptual point of view, but that does not imply that they have the same conditions. Profound difference appears in navigation of physical and virtual spaces (Burgess et al., 2002). In our physical interaction, we are limited to the capacity of our body and mind, in regard to how we are able to move, see, hear and touch and to what we can conceive and imagine (Sherman & Craig, 2003). In addition to that, virtual spaces have a potential to extend our senses and thoughts and create alternative semiotic agreements. Virtual space also has the function of being an image of reality, a simulation of physical space. It can work as a model world, where strict rules and limitations are defined, like in a game. This means that the virtual can be seen as both an extension and a limitation in relation to the physical. Virtual space is both "almost real" and "more than real".

One of the main conclusions from these examples regarding RQ1 is that it is not only the physical world that dictates the virtual but also the opposite. Virtual space both asks questions to the physical and answers questions from the physical, in a communicative process through an actor. The physical-virtual hierarchy shows to be arbitrary so that virtual space can be seen as an interface to physical space and vice versa. The architecture becomes an interactive interface to serve a certain purpose. Also, the transfer of meaning is mutual, so that experience from one space affects experience in another. Seeing creation of meaning as an act of communication, it is in the interplay between actuality and virtuality that the development of concepts in our physical-virtual world is made.

In this architectural design process, virtual space plays an important role in the development of concepts. The transfer of signs and knowledge between physical and virtual representations form a space for the creative work and the gestalt. With the properties of virtual space of being flexible and shared, the communication process reaches out of the architects' office to involve a larger social context. Architects will have to adapt to a code that includes this discourse of virtuality, meaning that reference to virtual space in the creation of physical space will be just as plausible as to other real-life architecture. For example, the design of a future museum of art might originate in the concepts of computer games rather than in historical buildings or physical urban spaces. This process is already underway, and present case exposes some aspects of this trend.

This case explores the relations between physical and virtual space on the levels of design, philosophy of design, and semiotics. It shows that even in architecture, in the creation of our physical environments, the separation between virtual and physical is not obvious. The creation as well as the experience of architecture is an embodied interaction where virtual and physical spaces connect. The embodiment works like a stage for the interplay between physical and virtual, where the connections are made. The space becomes an image and the image becomes a space. But they are not one. In a comparison between physical and virtual environments, we have to remember the difference in tradition and abstraction level of knowledge. We are only beginners in the exploration of virtual world. One of the most important ambitions with this thesis is to add to the expertise of creating virtual spaces. And, as this case demonstrates, this contribution will also lead to a development of the process of creation of physical architecture.

This case highlights the power of introducing metaphors as a way to contribute to the connection between physical and virtual space. And, through the use of metaphor, how a common place for the physical and virtual can be formed in the practice of architectural design.

The Case Revisited, 2020

Since 2008, I have been part of realising more than twenty architectural projects of different scales at Arctic Studio. I designed and built my own house in 2009 and since then I have specialised in private housing in my practice. The founding work of this case that we did back in 2006-2008 has still importance today. Our physical-virtual design concepts have formed a code and a language that we continuously use, speak, and transform. This is done not only by designing new physical buildings but also by exploring and transforming the design concepts in virtual space. TriAngle (Fig. 47 a) is Wedge-shaped volume adapted to the landscape. ConcreteBlock (Fig. 47 b) is a fusion of a block-shaped base and a prism-shaped roof and a project that was developed and realised only as virtual architecture. BeachBox (Fig. 47 c) is a block-shaped house with two 3x6x12 m stacked volumes. These projects are examples of how the four physical-virtual design concepts continue to find new contexts.

Figure 47 a. TriAngle (Gross, Wideström, 2013), Bua Strand. Photo: Krister Engström

Figure 47 b. ConcreteBlock (Gross, Wideström, 2015). In collaboration with J. Södeström

Figure 47 c. BeachBox (Gross, Wideström, 2012), Onsala. Photo: Krister Engström

CASE 2: PHYSICAL AND VIRTUAL SPACES FOR VISUAL ART

> *"But, after all, the aim of art is to create space – space that is not compromised by decoration or illustration, space within which the subjects of painting can live."* (Stella, 1986, p. 5)

An analysis of the properties of physical and virtual space could be done in many ways using all types of spaces. There are for example physical and virtual versions of shopping malls, role-playing games, conference rooms, libraries, urban spaces and universities that could be compared and analysed. However, there are a few points that can be made about art spaces and why they might be an interesting arena for spatial analysis.

First of all, experiencing visual art is about visual perception and interpreting two-dimensional images as space, similar to visual perception of architectural space which is a process where the interpretation of two-dimensional retinal projections as three-dimensional space is central. I use the term visual perception as described by David Marr as a proceeding from a two-dimensional visual array on the retina to a three-dimensional description of the world as output (Marr, 1983). The stages of vision include: a 2-D primal sketch of the scene, based on extraction of fundamental components such as edges and regions, a 2 1⁄2-D sketch of the scene, where textures and shades are acknowledged to provide depth, a 3-D model, where the scene is visualized in a continuous, 3-dimensional map. This means that, on a perceptual level, there is a strong connection between the perceived space (physical or virtual) and the meaning and idea of the conceptual space. On that perceptual/conceptual level, a comparison between for example a physical and a virtual shopping mall, the spatial context would not be as strong. The idea of a shopping mall is "to buy" so there is of course a spatial connection to the design and experience of the mall that should sell the products, but the purpose of the shopping mall is not the experience for its own sake. In contrast to that, a work of visual art can be seen as a "window into another world", which is one of the key aspects of virtual space; the transportation effect or the sense of being somewhere else. The whole art exhibition (physical or virtual) can also be regarded as a virtual world or an alternative reality in itself.

Secondly, the idea of art is to constructively interact with the viewer, to present the world in an alternative way, to provoke emotions and thoughts, and to question conventional ideas. This means that there is a constructive interaction between the audience and the work of art, which activates the viewers both physically and mentally and affects their perception of the world, including both themselves and the actual space where the artwork is placed. As comparison, a different type of space with a "quieter", less demanding and provocative relation between space, objects and users, such as a conventional living-room, would therefore typically not stimulate that certain innovative and constructive aspect of interactivity.

It was already in the Renaissance that the first important developments were made, with the invention of the central perspective and portable paintings. The concept of space has been a major concern in visual art throughout the history and especially in the 20th century the development of space representation has been dramatic, as presented by Christopher W. Tyler and Amy Ione *The Concept of Space in Twentieth Century Art* (Tyler & Ione, 2001). Also, the concept of space in 20th century art is a key issue in several artists' text, such as in *Working Space* by American artist Frank Stella. It is during the last century that the deconstruction of visual space in art has really moved forward with impressionism, cubism, illusionism and, in the last decades, the extrapolation into cyberspace and virtual reality. Moreover, spatial representations in paintings cannot be detached from cultural, metaphoric and philosophical ideals. It is also with this historical relation between image and space in mind that it is interesting to use different art spaces to analyse the relation between reality and virtuality.

Art exhibitions today are shown both in traditional physical art spaces, such as galleries and museums, and in virtual spaces on the internet and through other media. In order to compare physical and virtual spaces for visual art I have chosen to include two types of art spaces; the private art gallery and the public art museum. Here I assume that the visitors to the

private gallery are invited by the owner with the purpose to sell the artwork, while visitors to the museum can access the museum as part of public urban space with the purpose to experience the artwork. In this case, the art gallery is private property while the museum is publicly owned.

The aim of this case is to show the examples of public and private spaces represented as virtual space versus physical space (Table 2). The purpose is to test a semiotic analysis of the relations between physical and virtual space in a social context. This inclusion of private versus public in the example means that the spatial analysis also involves the aspects of experiencing and interacting with an art exhibition in relation to the social rules and patterns that apply in different settings. The social aspect of sign production is vital to an analysis of different spaces, in relation to their purpose and function. The social code forms a space, which relates to Lefebvre's argument that space is a social construction: "Social space is a social product - the space produced in a certain manner serves as a tool of thought and action.", as presented in *The Production of Space* (Lefebvre, 1974, translated 1992, p. 26).

Space	**Physical**	**Virtual**
Private	A. Physical Art Gallery	B. Virtual Art Gallery
Public	C. Physical Art Museum	D. Virtual Art Museum

Table 2 – The comparison of spaces for visual art

The actual examples of art spaces below are not in every aspect representative for all physical and virtual galleries and museums but are used to point out some of the key aspects of reality and virtuality in architecture for visual arts. The focus here is more on the interplay between the four spaces than on the properties of each space. It can be noted that in the examples of two private art spaces the virtual and the physical are two different galleries, while for the examples of the two public art spaces the virtual and the physical are both the same museum. As an example of limitations of the choice of art spaces, both the physical and the virtual gallery are privately financed galleries where the artwork is for sale. This choice excludes galleries that are more of public culture event galleries. The reason for this exclusion is that those galleries can be regarded as "in between" private art galleries and public art museums. Being a vital arena for the art scene, though, this type of space is an interesting possibility for a complementary study in future work.

A. The Physical Art Gallery – Arctic Studio


Figure 48. a) The opening as a social event b) Social interaction. February 2006


Figure 49. a) Focusing on the artwork b) Discussing the artwork. September 2006

Arctic Studio is an office for architecture and an interdisciplinary arena for art, architecture and design in Göteborg, created and run by Josef Wideström and Björn Gross. The physical art gallery in this example is a space of 85 square meters with white walls and ceiling, black floor and with an entrance door and windows towards a quiet backstreet. During the period that the gallery had existed up to the time of the exhibitions, around 500 people had signed up to be invited to coming events and between 50 and 150 people showed up for each opening. The events were sometimes conventional art exhibition openings with a number of visual art pieces on the walls and a bar that served the visitors snacks and refreshments (Fig. 48). The curators and the artists were present to discuss (and sometimes sell) the artwork.

At other times, the forms of the openings were quite different. Pictures (Fig. 49) above show images taken from a web camera at the cultural event *Kulturnatta* in 2006. At the opening, the audience got copies of fragments of the exhibited artwork, as an introduction to a game. The artist Håkan Berg worked with a theme called "the serious game" at the time, which inspired the curators to arrange this game at the opening. The task was to identify from which of the (quite similar) pieces that the fragment came. In a back room of the gallery a projector showed a series of still images from the web camera in real time, so that one part of the audience could experience the other's interaction with the artwork.

B. The Virtual Art Gallery – Exponeo

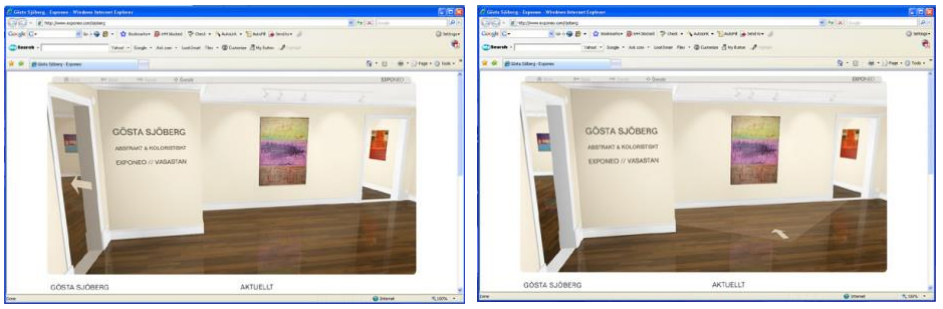


Figure 50. a) Entrance room b) Arrow indicating possible interaction

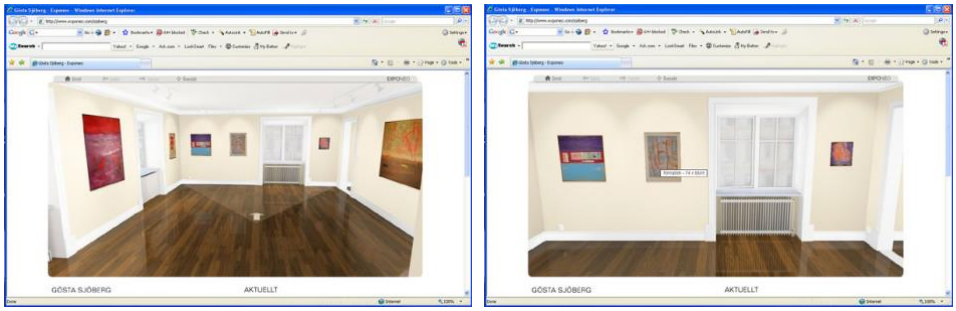


Figure 51. a) The main gallery b) Detail of the main gallery

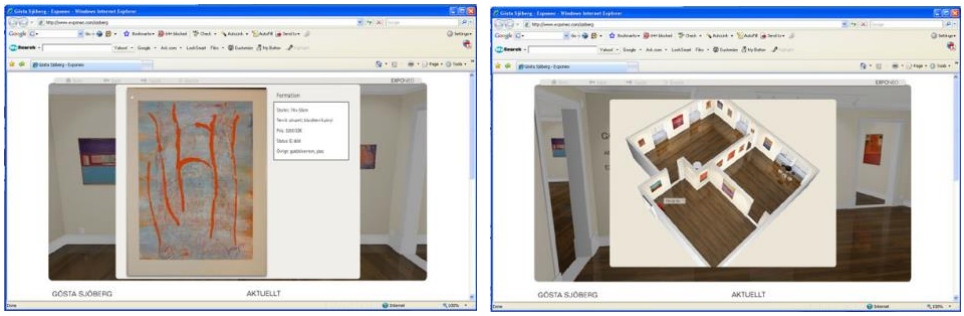


Figure 52. a) Close-up of a selected artwork b) Navigation overview

The Exponeo virtual art gallery is a virtual space for visual art on the internet. Exponeo is a virtual art gallery created and run by Gösta Sjöberg showing his own visual artwork.[44] This virtual space is not a model of a physical space and the gallery does not exist physically. It is a web-based showroom application that uses an image walkthrough plug-in to let visitors navigate in the virtual gallery and experience the artwork in a physical gallery-like environment (Fig. 50-51). The user is able to click and view selected artwork and get an overview of the gallery (Fig. 52).

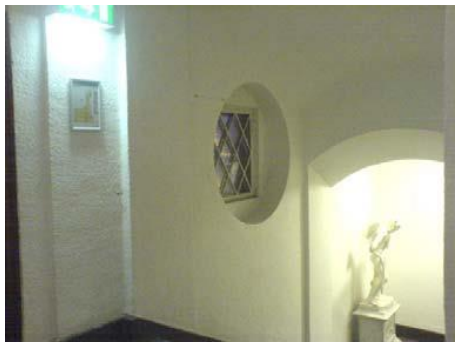
Just like in a physical art gallery, the work of the artist is for sale. The artist is present in the form of explanatory text, written in first person, connected to the visualization. There is no representation of other visitors or avatars, so each visitor appears to be alone in the gallery.

C. The Physical Art Museum – Göteborg Museum of Art

Figure 53. a) Urban environment

b) Entrance

Figure 54. a) Staircase with artwork



b) Warning signs, window, sculpture

Figure 55. a) Exhibition hall, 1

b) Exhibition hall, 2

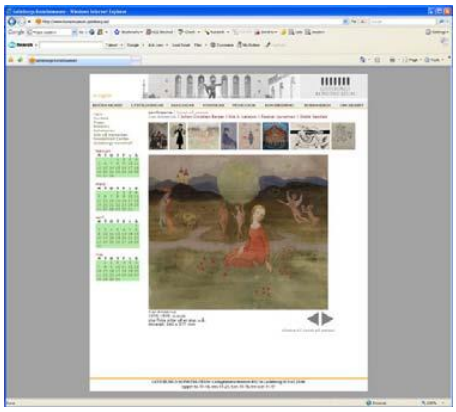
[44] See http://www.exponeo.com (screenshots taken in May 2007).

The Göteborg Museum of Art is a large and monumental building right in the center of the city, with the front façade working as a backdrop to the end of the main avenue (Fig. 53). The museum is situated at Götaplatsen, next to the City Hall Theatre, The library and the Concert Hall. It was designed by Swedish architect Sigfrid Ericson in 1916 and finished in 1923. My photos of the museum were taken in November 2006. The entrance is clearly announced and opens to a large public space. The interior is a quite complex structure of exhibition halls on different levels, due to the additions that have been made to the museum over time.

The museum shows a wide range of artwork with a collection from the 15th century to today. It has a Scandinavian profile but includes also work of the great French and Dutch artists. The museum also has an exhibition hall for temporary exhibitions.

D. The Virtual Art Museum – Göteborg Museum of Art Website

Figure 56. a) View of the exhibition space



b) View of a selected artwork. August 2007

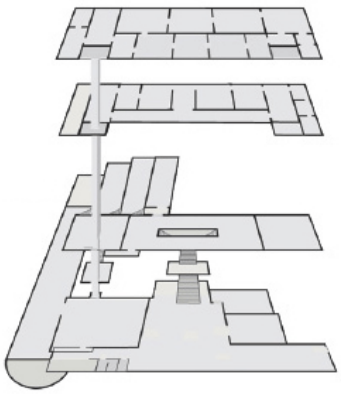


Figure 57. a) Navigation plan

b) Example of photo from website. January 2009

The website for *Göteborg Museum of Art*[45] uses a navigation plan combined with photographs of the exhibition spaces (Fig. 56) to create a sense of both presence and overview for the visitors. The website does not show a conventional 3-D model but rather a layered 2-D interface, just like the typical orientation plan that can be found in any entrance hall of a museum. To have a closer look at the artwork the user has to select a miniature picture above the photograph of the current exhibition space (Fig. 57).

The presence of other visitors is represented by people on some of the photos and also a calendar with ongoing activities at the physical museum on the left side of the web window (fig. 56). It is made clear for the visitors that the virtual art museum is a virtual representation

[45] http://www.konstmuseum.goteborg.se/ Captures in Fig. 56 are taken in Aug 2007, captures in Fig. 57 in Jan 2009. No important changes have been made in the web design between the two occasions.

of the physical museum. It contains photographs from the main part of the collection and at least one photograph from each physical exhibition space.

A & B – The Physical and the Virtual Art Gallery

A common feature of these two spaces is the exclusive social context. In neither A nor B a visitor would need a formal invitation, but both spaces address the visitors in a way that do not include the general public. In a strict sense, both galleries are open to the public (the front door is unlocked, and the website is part of the open internet) but the location of the spaces is not common knowledge. There is a sort of intimacy to the gallery, which comes partly from the home-like scale of the space and partly from the presence of the artist and the curators. In addition, every visitor is a presumptive buyer, which means that the gallery is also a commercial space for people with certain tastes or interests.

A noticeable representation in the virtual gallery is the similarity with the physical gallery atmosphere and visual signifiers. B appears to be a virtual replica of a physical art gallery, even though this is not the case. Why is this? One explanation to the use of separate rooms to walk through in B might be to introduce a spatial metaphor to add meaning to the artwork. But that does not explain the realistic impression in the virtual gallery. For example, how come that Fig. 49 b (in A) and Fig. 51 b (in B) both show a window and a heater? In the physical gallery those have practical functions, while in B they can only be seen as imitations of A. Using de Saussure's terms, the signifier is the visual appearance of a heater in B and its referent is a physical heater. But what is then the signified? The most probable answer lies in the commercial value of art. In a physical gallery every piece of art is given a certain value, shown as a sum of money on a list, corresponding to each title. That value is based on the prestige of the artist together with the prestige of the gallery, as a sort of agreement or consensus about the commercial value of art. If the piece of art would be displaced from the gallery or be removed of the artist's signature, it would have a much lower value. The art collector pays more for the context than for the actual work of art. In order to raise the value of the artwork, B uses visual signifiers for prestige, hence imitating A, in the spatial representation. Using Peirce´s model of sign process, the interpretant of A becomes the object in B.

Does this mean that B always imitates A and not vice versa? One example of the opposite transfer of signifiers can be found in the example with the game (Fig. 48). The game opened up the interaction between the viewers and the artwork, so that the players of the game had to "zoom" in and out and "click" on the selected piece in order to manage the game (Fig. 48 a). One section of the exhibition was composed on the wall in a 3x3 matrix and not in the traditional side-by-side hanging, like an interactive digital menu or game board. Also, with the real time web camera and projector, the audience had the experience of a digital media application. Another example where A uses signifiers from B is in the private home gallery. In an article in Göteborgs-Posten (Titti Thorsell, Göteborgs-Posten Bostad, p. 6, 2009-02-02 14) there is a home interview with Ted Hesselbom, the director of the prestigious Röhsska museum, who also collects art for his private collection. Two large photos of the article show a wall with a 4x3 matrix of 12 A4-sized Plexiglas boxes that "easily can change content, which happens frequently in this ever-changing home." The interpretation (interpretant) of this design is a digital representation, so that the interpretant of B becomes the object in A. This flexible art space is as interactive as a digital menu and the boxes are like file folders, the works of art being like files, and the materiality of the artwork is hidden behind the Plexiglas screens.

C & D – The Physical and the Virtual Museum

In the relation between the physical (C) and virtual (D) museum, it is clear that D uses signifiers from C in order to become a virtual replica of the physical museum. In C there is another form of prestige or confidence that has been built up over history as the art collection of the museum has grown. The picture of the front façade of the physical museum in the top frame of the web

site is an obvious sign for these qualities. The interpretants of C have become objects in D. The purpose of D is not so much the art experience, but rather to make the art collection accessible and to create an interest to visit the museum in real. C uses D in order to reach out, while D uses C for the authenticity.

Trying hard to be an authentic virtual replica of the physical museum, some spatial aspects can still not be transferred only by visual resemblance, like the idea that the visitors should be able to navigate through the museum. There is no actual purpose with the navigation model (Fig. 57 a) in D, other than being a copy of the information boards of C. The navigation model is too poor to create a sense of presence in the virtual space, and too complicated to remember as a preparation for a visit in the physical museum. Its only function is to separate the different collections, but that is already done more clearly in the 2-D web layout (Fig. 56).

The virtual space can here also be seen as an improvement of the physical space, an ideal museum. In C there are stairs to climb, disturbing objects and people that are in the way (Fig. 54-55), while D is quiet, clean and accessible (Fig. 57 b). I even had to take the pictures of C for this article on the sly, since the museum's policy at the time was that no photos may be taken without special authority. The person in charge explained that the main reason why photos cannot be taken of the art spaces (even without close-ups on the artwork) is that they do not want any unflattering pictures to be spread. This means that the physical museum wishes to appear as the virtual idealization.

A & C – The Physical Gallery and Museum

The social context is an important factor in the physical art spaces. In the face-to-face contact in art exhibitions people relate to that particular social code. The museum, being more open to the public audience, the visitors can be more anonymous and there is also a mix between highly "code-integrated" visitors that have assimilated the code of the art museum and, for example, group visits from schools, guests of the museum café, or homeless people in the entrance lobby. Nevertheless, the idea of the art exhibitions in both A and C is that people experience and interact with artwork in real-life. This experience is affected by the presence of other people and the social codes that apply. One might for example pretend to be impressed or understand a certain artwork because of social reward. In the case of very challenging content, one might feel too embarrassed to stand close staring at the picture or sculpture, but rather glance at it from a distance.

In regard of the difference in scale and organizational structure, A can be more flexible than C in communication with the art scene. A gallery has a closer and more personal relation to its audience and artists, which makes it easier to pick up new trends and ideas. In order to get closer to that social context, museums arrange small-scale art events with invited guests. There are also examples of new ways of marketing museums that remind of galleries, like when the Museum of Modern Art in Stockholm made a gallery-like event in 2006 and even sold a few works of art.[46]

B & D – The Virtual Gallery and Museum

In my examples of B and D there is not much room for social interaction within the spaces. However, as both B and D are places on the internet, they are already sub-spaces of a larger space that is ever so open to social interaction. This can be seen as an indirect interaction that takes place in blogs, newsgroups and chat rooms. In the development and improvement of the virtual art spaces, designers, artists and producers rely on this shared space, or code, that the internet constitutes. New and improved applications are created that are used as inspiration in others and so on in a constant flow of sign production. The pattern is that smaller and independent activities (subcultures) come up with new concepts that later are picked up by

[46] Årsredovisning 2006. http://www.modernamuseet.se/

larger institutions and companies. In that sense, there is probably more transfer of knowledge from D to B than the opposite. The interpretants of B that become objects in D have more to do with the prestige of the museum.

Sign Process and Transfer of Meaning

To summarise this case in relation to sign process, it is clear that new signs emerge in the interplay between the different spaces. The introduction of virtual space has made an impact on the code, spaces for visual art, so that aspects like interactivity and accessibility are now important parts of the sign-object-interpretant triads, and of the connections between interpretants and objects. The example shows as well that virtual spaces work not only as objects in relation to physical spaces but also as interpretants in this process.

The two-dimensional layout of this example makes this analysis a bit more complicated. The aspect of physical vs virtual is of course only one of many dimensions regarding spatial analysis. This example includes a social dimension using the private-public aspect, but a richer analysis could include even more dimensions (economic, historical, geographical etc). The introduction of a second dimension opens up to a multi-dimensional interplay that puts the simplified physical-virtual sign relations in question. Meaning is transferred from signifier to signifier through a multi-dimensional web of associations and agreements that only partly relate to the relationship between physical and virtual spaces. This problem of certainty does not imply that comparisons of physical and virtual spaces are not passable. It rather points at the validity of deconstructivism in this discussion, where Derrida's concept of traces seems more fruitful than structuralist sign relations.

	Influence Physical → Virtual	**Influence Virtual → Physical**
Private	A → B: Commercial value, Prestige	B → A: Interactivity, Social context
Public	C → D: Confidence, Authenticity, Prestige	D → C: Accessibility, New concepts

Table 3 - Influence between spaces A-D

Table 3 above is a diagram showing the structure of the relations between the four spaces, regarding the influence that one type of space can have on another. It does not cover all the aspects of the text above but can be seen as a board game for the interaction. The table is meant to illustrate the complexity of different possible connections. Since the spaces affect each other in this ongoing interplay, it is not given how to position and define sign relations in this context. Like Derrida describes, the signs are both expressing and indicating. Metaphorically, the figure above might be seen as a frame for the space in between, where the four worlds can meet.

The fact that one space uses signifiers from another or that meaning is transferred between spaces does not automatically imply that the spaces convergence. For example, between A and C there is an interchange in some respects, but there is also a contradictory force of protectionism. My analysis actually shows that the interplay is more vital between physical and virtual (A & B, C & D) than between the two social contexts (A & C, B & D), having a more open dialogue and mutual gain in this example. In the relation between physical and virtual space it is not given that the virtual space is only a digital version of the physical. Virtual spaces also have qualities that are transferred to physical spaces. Interacting in a physical-virtual world, the experiences are real regardless of virtual or physical.

CASE 3: THE BALTIC SEA FORUM

This case is presented as a personal testimony of the initial part of a multi-disciplinary design project that was executed in 2008-2009. I have chosen to focus on a specific event of the process that had impact on the project outcome. This event also works as a significant case for exploring the research questions. The focus of this case is on RQ2, how metaphors support the connection of physical and virtual space, and RQ3, how a common place can be formed for the physical and virtual in the practice of design. The description of this case is based on my own notes from seminars, meetings and phone calls during the project. In the second part of this case there is a presentation of my design contribution to the project, in the form of drawings and text.

Background

In February 2008, I was invited to a seminar arranged by GMV[47] at Chalmers to give a short talk on experience-based edutainment (Swedish *Framtidens Faktaupplevelser*). The purpose of the seminar was to give input to the planned Baltic Sea Forum science centre (Swedish *Forum Östersjön*) on the south side of Gotland, the largest island in the Baltic Sea. The seminar was led by former Swedish minister of affairs Allan Larsson, together with the operative management of the project. I was then, together with a handful of the other participants, invited to come to the site of this Baltic Sea Forum in Vamlingbo on Gotland a few weeks later. The group was shown around the premises, an 18th century farm that was to be transformed into a meeting point for research and education on different aspects of the Baltic Sea. The centre was planned to open in August 2009 as a forum for both researchers and for public visitors. The ideas for the content of the Baltic Sea Forum were most diverse; the project leaders had plans for an aquarium with live Baltic Sea fish and plants, several exhibitions about environmental threats, ecosystems, transport systems and lost ships, interactive digital research applications and games, and photographic art. Also, there was going to be built a conference area, a foyer and other facilities. All of this had to be fit into a two-story, 8 by 40 meters barn (Fig. 58 below) with strict cultural heritage regulations about keeping the exterior intact.

Figure 58. Photo of the south facade of the barn

Figure 59. 3-D model of the attic (roof removed)

Conceptualisation of the Design Problem

The old barn in Vamlingbo was actually going to be transformed into a physical-virtual space in order to fulfil the program of the Baltic Sea Forum. The project management wanted the invited group to discuss and give ideas for the content and form of the digital applications. The project plan was to renovate and redesign the building in order to meet the physical needs (conference room, toilets, entrances etc.) and then merely put different physical and virtual

[47] The Centre for Environment and Sustainability, GMV, in Göteborg, Sweden is a network organization at Chalmers University of Technology and University of Gothenburg that promotes research and education for sustainable development.

exhibits into the space. I opposed to that idea and said that there had to be a congenial concept that could embrace both the physical and the virtual spaces of the Forum. Was that not the essence of the idea to define a physical node in the Baltic Sea region that could link all these virtual spaces together? This Forum had all the conditions to become a space between reality and virtuality.

I decided to see the barn as a stage. What is the drama that is to take place here? Who are the actors and the audience? The answer lied in the Baltic Sea and in the strength of my own arms. While all the other visitors went back inside the mansion to continue the conference, I stayed alone in the barn thinking about the sea. There was no staircase or ladder in the barn so one could only see the ground floor, the roof beams working as a compact grid that obstructed the view into the attic upper floor. Even though there was no slab above me, I felt locked under the surface that the semi-transparent beam grid constructed. I just had to get up. In the middle of the barn there was a one-meter high wall that I could climb, but standing on that support I could just barely reach the beams with my hands. I could still not see the upper floor. I grabbed the closest beam and heaved myself up, so that my chin reached above the slab. It felt like I could breathe again. The whole attic opened up and I could see the grid of beams from above (Fig. 59 above). The sensation was just like coming out of the water, above the surface. I realised that this was the answer to my questions about this space and to the concept for the Baltic Sea Forum: above and under the surface, the dialectic of *surface and depth*. I went back to the conference room and when it was my turn to give a short presentation, I skipped the notes I had prepared on edutainment and instead I talked about the "revelation" I had just had.

It was no doubt that this idea hit right on the spot. We soon started talking about what was above and under the surface of the Baltic Sea and the concept of the Forum, both concretely and metaphorically. It soon became obvious that some physical exhibitions would fit best below the surface, like the aquarium and the exhibition about shipwrecks. The photo art exhibition with views over the Baltic Sea and the archipelagos would be perfect for the space above the surface. But where should the conference room be placed? Deep down under among the fish and pollution threats or above the waterline in the fresh air overlooking the sea? The group also started talking about the digital applications as spaces and where these virtual spaces would exist in relation to the Baltic Sea and the Vamlingbo Forum. The initial project idea about first solving all the physical spaces and then just adding digital "kiosks" into the building was gone (or postponed). During the half an hour that this discussion took place the boundaries between physical and virtual space were broken, by the power of the "surface and depth" metaphor. The different parts of the set were now all on the same stage.

Design Proposal

After this session the project manager gave me the task to take this concept further, in text, drawings and models. A meeting with the person responsible for the aquarium was also arranged. In April 2008 the project manager came to Gothenburg to see the result of this work and bring it back to the project management group.

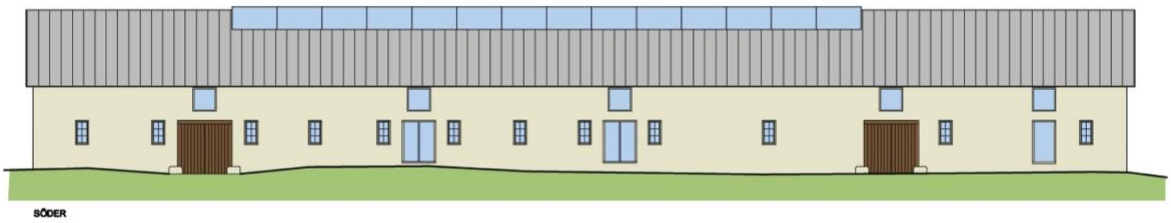


Figure 60. Baltic Sea Forum presentation – building facade

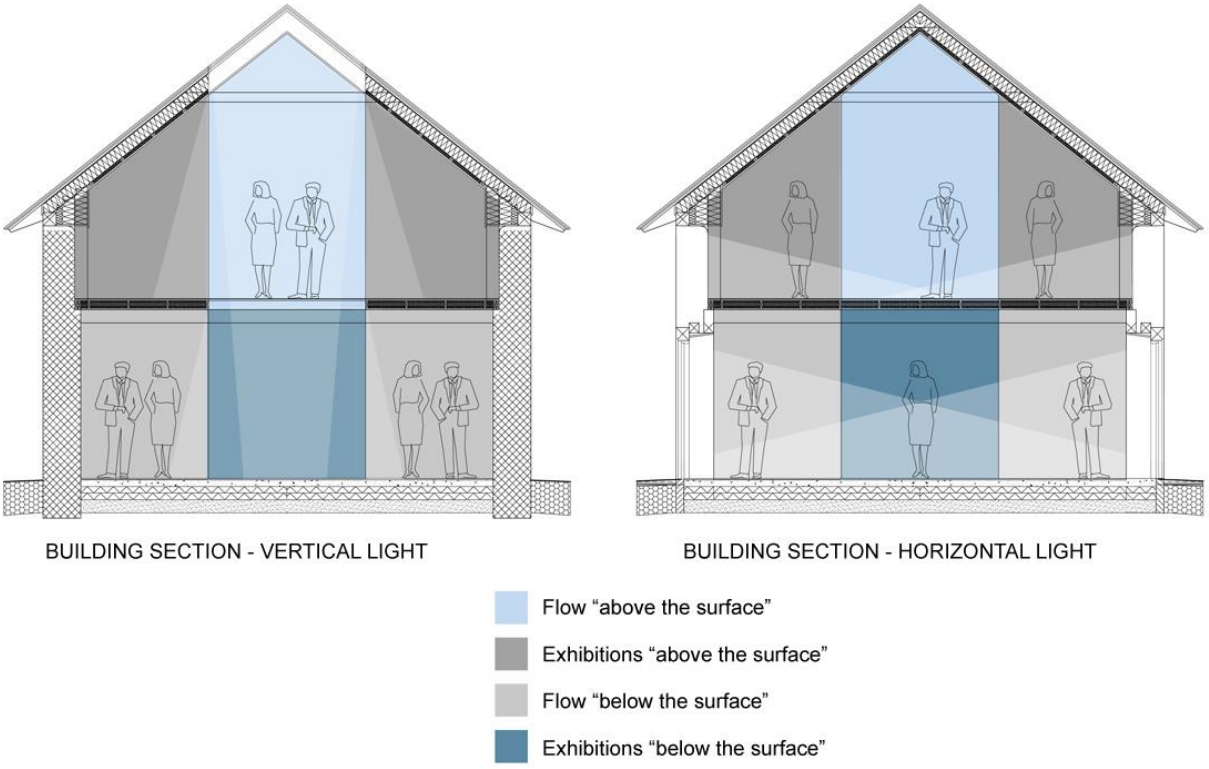


Figure 61. Baltic Sea Forum presentation – building sections

The concept of the proposed space is a physical-virtual environment that claims to be present both in reality and virtuality. The unifying links between the physical and the virtual are the “surface and depth” and “stage” metaphors. The extension of the stage is defined as the interior of the barn, thus leaving the exterior “off stage”. The surface has its physical representation in the floor slab. In the drawings of the building sections (Fig. 61) we see the space inhabited by visitors to the Forum. They have entered the stage and work as both actors and spectators of the Baltic Sea drama. By the means of perception, transparency, transportation, attention and social factors the visitors become present in a metaphorical Baltic Sea, making the space virtual. At the same time the materiality of the barn, the tactility and sounds of the environment, and the view over the surroundings attach the space to the physical world.
When the visitors move along the interior axes of the barn the natural light shifts from coming from above (Fig. 61 left) and from the sides (Fig. 61 right).

This effect is achieved by a new roof lanternine (Fig. 60) and glass doors replacing existing wooden doors. The lanternine opens a view to the sky that makes the “surface” more present, while the side windows on the attic accentuate the “water level”. In the sections where the light comes from above there is a glass floor that separates the attic from the ground floor, where the aquarium is placed in the centre of the volume (dark blue zone in Fig. 61). At the entrances of the building the light comes from the sides, emphasizing the axes through the building and perpendicular to the volume. This shift of light and flow is meant to animate the life both above and under the surface. Also, the existing slab beams are lowered so that the new slab makes it lower to the ceiling on the ground floor and consequently higher on the upper floor, which emphasizes the difference between above and under the surface.

The exhibitions are located in the dark grey zones (Fig. 61 left) on the upper floor and in the dark blue zone (Fig. 61 also left) on the ground floor. They are placed in the sections of the barn where the facades are more closed and the roof open, giving more focus to the exhibitions. The exhibition spaces are meant to be represented in the continuum of physical to

mixed physical-virtual to virtual, in the manner that each project subgroup develops their presentations or applications. These spaces will work as sub-settings of the main Baltic Sea setting, linking the individual exhibits to a unifying exhibition space.

Reflecting on the Design Process

There are two sides to the conclusion of this work. First to be mentioned is that I was only part of this initial phase of the project. The project management was very enthusiastic about this contribution but chose to continue the realization of the project together with architect Johan Celsing and Fururniture exhibition designers, partners that the organization of Vamlingbo and project owners Heligholm Utveckling AB had collaborated with before. On the website of Forum Östersjön,[48] the brief presentation says that the concept or "profile" of the Forum is: Interactivity, Presence, Surface and Depth, and Beautiful Baltic Sea. There is no mentioning of my (or that of Chalmers) contribution, even though I definitely introduced the ideas of both "presence" and "surface and depth".

Secondly, the case itself is ever so rewarding regardless of the actual production of the design. The process is evidence of how powerful metaphors can be in resolving the physical-virtual divide. The specific metaphors "stage" and "surface and depth" worked well here as a method to unify physical and virtual spaces. One could oppose to the generalisation of this case and also to the validity of the result when the process was cut off mid-way. However, to defend the possibilities to draw general conclusions from this case it can be said that:

a) The barn is neither an especially stage-like space, nor more easily adapted to the "stage" metaphor than other buildings. It was the definition of the interior of the barn as "on stage" and the exterior as "off stage" that gave the conditions and style of this particular piece of work. There is no obvious reason why the same approach would not work elsewhere.

b) The project groups were initially stuck in a divide of physical and virtual space that made it difficult to see any commonness in, for example, the physical aquarium and the virtual seawater flow simulation. This separation was overcome by the metaphor of "surface and depth", a metaphor that actually had what Ricoeur calls "the power to redescribe reality". The enthusiasm for this idea indicates the potential to use this method in other situations where a physical-virtual space is at hand.

c) People involved in the project came from many different backgrounds and with different competences and expectations; there were artists, scientists specialised in different fields, economists, and politicians. In spite of those differences, the metaphor was taken in by the participants and affected the common understanding of the project. This shows that the method exemplified in this case has the capacity to unify different spaces of understanding, in the way that conceptual metaphors work according to Lakoff.

The scientific validity of this case can be debated, mostly due to the lack of proper documentation in qualitative data through interviews or by other means. This documentation was planned to take place during the process but did not work out when the communication with the project group was interrupted. One could also argue that the relative success of the choice of metaphors here was just a strike of luck; what would have happened if another

[48] http://www.forumostersjon.se, 2011-05-01

metaphor had been tried instead? The best answer I can find to that question is that the "surface and depth" metaphor came to me as a result of my own openness to the situation and my "presence on stage". It was the conscious choice to see the space as a stage that worked as the founding condition for the next step. Most likely, other metaphors came to my mind when I visited the site but it was the "surface and depth" metaphor that caught my interest because it fitted in and started to communicate with the "production of discourse as a work" as Ricoeur puts it. I could see the potential of this metaphor in relation to the composition, genre and style of the Baltic Sea Forum. The surface is a strong structure or frame when it comes to arranging elements of the set, the science centre genre of "serious fun" has a lot to do with surface and depth, and the particular style of this piece of work is somewhat congenial with the metaphor. As stated about theatre stage design, creating this physical-virtual space is "the manipulation and orchestration of the performance environment" (McKinney & Butterworth, 2009). The notion that the metaphor "came to me" indicates that the metaphor was actually the subject of this process while I worked as an object, a vehicle that transferred the solution that was already there.

This case highlights the power of introducing metaphor as a way to contribute to the connection between physical and virtual space. And, through the use of metaphor, how a common place for the physical and virtual can be formed in the practice of architectural design.

CASE 4: THE MUSEUM OF NATURAL HISTORY

This case is a description of the exhibition spaces of the Museum of Natural History in Göteborg, followed by a discussion on how virtual spaces could expand the existing physical spaces. The purpose of this case is to explore RQ1, where the physical space of a museum is given and virtual spaces of content are added. There is no proposition of a particular design in this case, but rather a discussion around the aspects of physical-virtual space in relation to the conditions of this museum. The aim of this discussion is to test the overall hypothesis that the stage metaphor can contribute to connecting virtual and physical spaces in this context.

Background

The Museum of Natural History opened already in 1833, making it the oldest museum in Sweden. It was in 1923, the year of Gothenburg's 300-year anniversary event when so many other venues opened, that the museum moved into its new building in the Slottsskogen park. The red brick stone building in traditional style rises on the top of a hill overlooking the park. Visitors enter the museum through a more modern extension built in 1981. The exhibitions fill two floors in the building with two main halls. The first hall is the Mammal Hall (Fig. 62, *Däggdjurssalen*) with an exhibition of stuffed mammals in glass displays. The centre piece here is the African elephant that has been one of the most important attractions since the presentation in 1952 (*En historia om en elefant*, 2007). The appearance of these animals is quite naturalistic, and they are if not virtual but artificial in the sense that their postures and bodies are constructed in order to create an illusion of life. Animal life is staged for the audience in order to create authenticity. Around this hall there are other exhibitions arranged in the surrounding corridors. These exhibitions are more informative with a pedagogical idea to let the visitors walk from "lower" to "higher" life forms following the order of the displays. This order is however somewhat confusing since the 1981 entrance extension of the museum connects halfway on this route. The second main hall is the Hall of Whales (Fig. 63, *Valsalen*) where the world's only conserved blue whale is displayed (*Malmska Hvalen*, 2006). According to the presentation of the museum, the animal was actually put into this custom-made hall before the building was finished and then the last wall of the hall was raised. The whale construction is made of wood and the skin is attached with copper nails, all of which is quite obvious to the audience, making this piece of attraction less naturalistic and more of a 1:1 model of a whale. What makes it unique and exiting is the story behind it; the way it stranded and was found just outside Gothenburg in 1865, how conservator August Malm managed to fulfil his dream to conserve this huge creature, and then how the whale toured and finally ended up in this museum (*Malmska Hvalen*, 2006). Also on special occasions, the mouth of the whale can be opened to let visitors walk around and sit down inside the whale that is decorated with textile material. The whale has become a stage for this story.

Figure 62. The Mammal Hall with the African Elephant. Photo: courtesy of the museum.

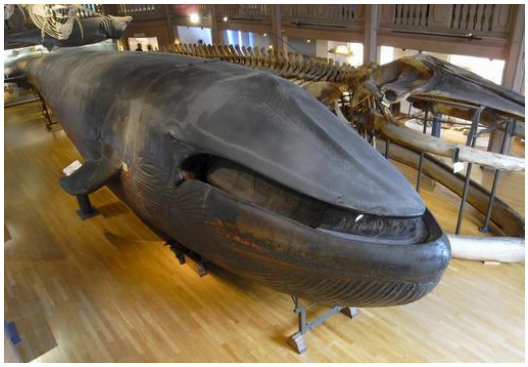


Figure 63. The Hall of Whales with Malmska Hvalen. Photo: courtesy of the museum.

A small tower with windows rises over the roof line of the museum building. This tower serves as a light lanternine to a special feature of this museum called "diorama". A diorama is a staged display of nature that one viewer at the time can observe through a small glass window (Fig. 64). The illusion of a vast landscape is accomplished by the narrow field of view, a detailed set of artificial nature elements, and a painted concave backdrop in combination with stuffed animals (Fig. 65). These dioramas were introduced in the late 19th century with the aim to show animals in their natural environment along with an ambition to bring botanical museums "back to the nature" (Wonders, 1993). The dioramas of the Museum of Natural History in Göteborg were designed and built by botanical expert and painter Olof Gylling, working with materials like metal thread, paper, textile, and paint in order to create the optical effect of each diorama (*Dioramor av Olof Gylling*, 2006). The suggestive effect of this technology is an experience of a virtual space. The diorama includes all of the aspects of presence in virtual space mentioned before, perception, transparency, transportation, and attention, therefore becoming a retroactive explanation of today's computer-generated virtual spaces. It is just as impossible to enter the actual physical space of the diorama as it is impossible for the human body to physically enter a virtual space. What is not included in the diorama is the aspect of interaction. It is rather a manifestation of the opposite, a conservation of both time and space as a "frozen space" that always stays the same, no matter how much the world around it might change. When this space is so static it is rather the mirrored effect becomes clear; when a person comes back to look into the same peephole again, he can notice the change in himself and the world around him in contrast to that frozen space. So maybe self-interaction is the true dimension of interaction with the diorama? But in that case, can we not say that all objects, like for example photographs, are interactive in the same way? Yes, but with the diorama this phenomenon lies in properties of the medium, or the "message" as McLuhan puts it (McLuhan, 1964). Coming back to the same diorama to see the same scene again is like coming back to a theatre and see the exact same frozen scene presented as last time. It gives a unique sense of frozen time as well as space.

Figure 64. A diorama scene of Stora Karlsö (Olof Gylling, 1923). Photo: courtesy of the museum.

Figure 65. Diorama of a Swedish mountain (Olof Gylling 1923). Own photo, Feb 2010.

In the modern extension of the museum there is an open space for temporary exhibitions. In 2010, there was an exhibition called *The green lung of Gothenburg* showing a walk-in model of the park areas where both the museum and the botanical gardens are situated. The exhibition space is a sort of playful area with a mix of toys, stuffed animals in glass display cases, and wall photographs. This shows the museum's ambition to become more up to date and connected to its surrounding. The temporary exhibition tries to be more interactive and open to interplay between the audience and the content. The audience is invited "on stage" and they become actors in this space. It can be said that the design of this exhibition is not taken to its full potential, creating some confusion about what to do and experience. However, the space

is interesting since it is different from other spaces of the museum, being situated in the modern extension and separated from the traditional atmosphere of the older part.

Figure 66. Animals in glass display in temporary exhibition space. Own photo, Feb 2010.

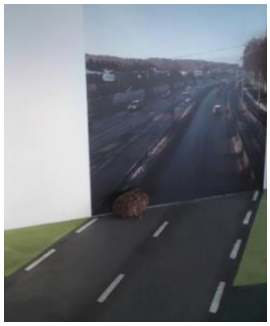


Figure 67. Setting in temporary exhibition. Own photo, Feb 2010.

Figure 68. Exhibition hall, with killer whale. Own photo, Feb 2010.

Design Problem

In the spring of 2010, I got in contact with Ann Strömberg, head of the museum (and former colleague as project manager of the IT University of Göteborg), in order to investigate the possibilities of collaboration. In June 2010 a meeting was arranged with the project group that works with the development of the exhibitions and the activities at the museum. The project group is working with strategies to add new experiences to the museum and to develop the existing exhibitions and activities. According to Strömberg, this project has a time perspective of five years, starting in 2009. In the museum's annual report of 2008, it says that "An exhibition project group has started to develop strategies and programs for our base exhibition that will constitute the foundation for our coming major effort of change" (Translated from Strömberg, 2009). One of the most important questions that the group deals with now is the introduction of digital media into the exhibitions. Today all content is presented physically, in animals, objects, paintings and posters. What are the possibilities with digital media that could enhance the visitors' experience? What are the dangers or back sides of introducing new media? Other well-known natural history museums, like the ones in New York[49] and Stockholm[50], have introduced a wide range of digital media into the exhibitions and also radically changed the presentation of the physical objects. Other research on using VR in museums show how the physical environment can be extended using VR (Charitos et al., 2001). In our meeting in June 2010, the project group expressed worries that such a change of the Museum of Natural History in Göteborg would "destroy the soul" of the museum and lessen the current main attractions of the museum. The digital representation of the museum is limited to the web site[51] that presents the exhibition and activities in text and images. There is also a QuickTime panorama of the Hall of Whales. There is not much on the website about the exhibitions that cannot be experiences in the real museum, apart from some documentation of previous activities and a section called "play and learn". A feature that is unique for the website is the "photo gallery" with close up portrait photos of 120 of the museum's animals. An important use of the website is a search function for items, images and documents related to the field of the museum, according to the annual report (Strömberg, 2009). In 2008 the museum collaborated with Skövde Högskola, which resulted in the computer game "the good life" that could be played at the museum during the Science Festival of Gothenburg. In the dialogue with the project

[49] American Museum of Natural History, New York. https://www.amnh.org
[50] Swedish Museum of Natural History, Stockholm. https://www.nrm.se
[51] Museum of Natural History, Gothenburg. https://www.gnm.se/

group, they brought up the fact that there is little connection between the physical and digital representations of the museum.

Design Proposals

To this project group I presented the idea to see the museum as a stage, and also as a set of multiple stages. This concept addresses the questions of what agreements that are needed, what expectations the museum has, and what experiences the museum wants to give. What are the roles of the staff working there and of the visitors coming there? Who are the audience and the actors? These questions need to be discussed in order to set the conditions of the stage and stages. It is important to point out that the change and development of the museum can be about making new agreements, just as well as changing the appearance and features of the exhibitions. For people working with museum exhibitions the notion of stage is not farfetched; museums have a tradition of staging objects in a contextual environment in order to create a sense of "being there" for the audience. In the diorama booklet of the museum it even says that Linné[52] thought that "A museum should give a concentrated image of the world. A natural history collection should be arranged as a theatre stage to show the shifting dimensions of the world" (Wonders, 1993). I believe that it is important to take this idea further when it comes to integrating digital media in the process of changing the museum's exhibitions. Here follows a list of examples of how virtual and physical space could co-exist in the exhibitions.

1. Virtual dioramas:
   Just opposite of each existing diorama (in the corridor close by) there could be a screen showing digital images of how that particular natural environment looks today, as a sort of mirror of one virtual world into another, but still referring to the same physical world. This idea was already in the summary of possible projects presented by Ann Strömberg in spring 2010.

2. Virtual backdrops:
   Replace some of the existing painted artworks that are placed behind animals (Fig. 69) with projections of virtual environments. These virtual backdrop spaces could be static images, animations, movies, or interactive 3-D environments showing the animals in their natural setting. Here, it is important to consider the different colour spaces of physical and virtual space (as described in Fig. 24), so that lightings of the physical environment vs the screens and projections of the virtual overlay come together in a coherent design.

3. Interactive soundscape:
   Add a soundscape to the exhibitions, linking all or some of them together in an interactive environment that follows each visitor's movement. This can be done with tracked headphones. The soundscape could include environmental natural sounds (auralization) and/or information on a higher level (sonification). A soundscape creates a space in itself and has the capacity to gather different spaces together on the same stage.

4. Flexible exhibitions:
   Introduce interactive virtual spaces to the temporary exhibition space. This opens up

[52] Carl von Linné (1707-1778)

this space to a higher degree of flexibility and possibilities to distribute and share exhibitions with related museums and other organizations.

5. Connect the website and the museum:
   The website and the museum exhibitions could co-exist in order to enhance the before-during-after perspective of the visit to the museum. The website has the potential to create expectations that are related to in the visit to the museum and then form experiences that are brought back out after the visit. This means not only that the exhibitions on the website become representations of the exhibitions of the museum but also the reverse, that the exhibitions of the museum become representations of the exhibitions of the website. This would manifest the mutual dependence of the physical and the virtual spaces of the museum and conceptually merge the two worlds together on the same stage.

Figure 69. Painted backdrop behind a model of a dinosaur skeleton.
Own photo. Feb 2010.

Staging

These examples show, on different levels, the potential to integrate physical and virtual spaces and objects on the same stage of the museum. Here, the virtual spaces work as overlays on the existing physical spaces that form sub-stages of the overall stage of the museum. In the renewal of the museum, the connection between physical and virtual can take place on this stage. Future collaboration with the museum's project group will have to investigate these possibilities further. An important issue that needs to be addressed in this case is the question of authenticity. What is the museum's view of "truth", of scientific reliability, and how is this affected by the staging of knowledge and ideas? It is vital to discuss how the interplay between audience and exhibitions appears as true.

From a research perspective, the potential for a fruitful case seems promising, as the efforts of changing the museum's exhibitions are essentially "production of discourse as a work". The stage metaphor works conceptually well in this context, however not in a too obvious way so that the introduction of this concept becomes meaningless. Seeing the museum as a set of stages, additional conceptual metaphors could be developed within the different sub-stages. In that way, the language of the museum can change so that it is not just the appearance that changes in this process of renewal.

CASE 5: THE EMERGENCY RESPONSE CENTER

This case is an application of the concepts of physical-virtual space to the field of crisis management in a Rescue Service emergency response centre. The process of this work was done in 2010, in collaboration researchers and professional practitioners of this field, through informal interviews and study visits. In the first section I present how the physical-virtual space is organised today and what efforts are made to introduce new spaces into this system. I then discuss this spatial architecture in relation to the stage metaphor and present some ideas on how the field could benefit from seeing the emergency response centre in this perspective. A discussion on the topics of RQ1 and RQ2 is presented, in order to address RQ3, how a common place for the physical and virtual can be formed in the practice of design.

Background

The milieu of this case has its centre in a research group at the Applied IT department at the University of Gothenburg that works with crisis management and specifically with IT and information systems in emergency response. The group has been working with implementing new technologies and systems, mainly mobile phone based, and has also studied the Rescue Service organization's use of different systems. In the spring of 2010, I was invited to participate in this work in the role of an observer with a different perspective on this field of work and I also took part in a research application process.

In emergency crisis management situations today, decisions are made in a mixed physical-virtual space. Virtual environments are interconnected both in command centers and in actual emergency situations (Landgren, 2007). The hierarchy and structure of these decisions rely on an established system of authority, leadership, communication, and collaboration. Previous studies on VE's show that the degree of immersion in a comparison of different VR interfaces affect social structures, decision making and leadership, so that the person with the more advanced technology or interface is considered the leader of the group (Slater et al. 1999). Further studies (Wideström et al 2001) show that people solving the same task together in real and virtual settings contribute unequally to the task depending on the interface to the VE. Different spaces mean different context with different sign relations and codes, so that interpretations and decisions depend on the space where the interpretations are made. This means that in a complex spatial system of information systems and information technology, like the emergency response centre, the decisions depend on the properties of each space and the relationship between different spaces. The issue of how to organise the physical and virtual spaces used in emergency crisis management seems therefore important to the development of this field. This case complements the previous ones in the sense that the context is quite different; the culture of the Rescue Service is different from that of architectural design, art spaces, science centers and museums, the time perspective is different since the time scale in an emergency response centre can be a matter of seconds and minutes, the space is not open to the public, and the organisation of both spaces and of people's roles is different.

This study takes a semiotic and hermeneutic stance in order to analyse and take the spatial relations further in the context of crisis management in emergency response. The questions asked are:

1. How does the interplay between physical and virtual space work in crisis management today? How are physical and virtual spaces organised and how do they affect leadership, collaboration and decision making? What decisions are made based on misunderstandings and different interpretations in different spaces?

2. How can the organisation of real and physical spaces be improved in relation to leadership, collaboration and decision making?

The emergency response centre in this case is the Rescue Service of Gothenburg (*Räddningstjänsten Storgöteborg*) with its physical central location in a building connected with the Gårda fire station, near the centre of the city. According to the *Action Plan* of the Rescue Service (Räddningstjänsten Storgöteborg, Dnr: 0196/07), its task is to prevent and limit accidents, to plan and execute rescues, to act in the afterwork of accidents, and to contribute to crisis management of the society. The Rescue Service has identified possible threats of accidents as highly populated high-rise building areas, industries, petro-chemical production, public event venues, and centers of decision and education. There are areas of the region with interest for the cultural heritage as well as unique nature in the surroundings. Transport is also an important factor for rescue and Gothenburg has a big harbour area as well as airports. In the south there is also a nuclear power plant. The *Action Plan* also points out the possibility of terrorist attacks and the vulnerability of the society when it comes to complex technological and information systems that are connected globally. Firefighting is noted to be the most important task, and with an increased number of uniquely designed houses, the consequences of building fires are therefore yet to be seen. According to the *Action Plan*, there is also an increased importance of weather phenomena, such as storm, flooding, and extreme winter.

Since five or ten years, the Swedish rescue services are in the process of introducing new information and communication technologies (ICT), especially on the operative level of work. Previous studies (Bergstrand & Landgren, 2009; Landgren & Nulden, 2007) point out that there are many ongoing implementations of different types of ICT for rescue service work, while there is some confusion about how to actually use ICT in the organization. Mobile phones have been introduced in order to open up for new portable services and emergence response centers have been equipped with multiple display systems in order to keep up with different incidents and different aspects of the same incident. In this research "enacted sensemaking" has been used as a term to describe how the professionals of this organisation are seen as actors rather than users, and how the organisation emerges from such enacted sensemaking (Landgren & Nulden, 2007). This idea links closely to the semiotic and hermeneutic perspectives of these relations that are discussed in this thesis. From a semiotic perspective, the sum of all "enacted sensemaking" of the actors and their sign relations form the code, the space, of this organization. It is this "act of communication" that creates meaning and knowledge, as Eco states. Hermeneutically, sensemaking itself is a process of expectation, agreement, and experience that constitute the discourse of the rescue service. In the line of these ideas, virtual spaces in the form of different types of ICT together with the physical spaces of the Rescue Service are therefore just as much a result of as a condition for this sensemaking.

Design Problem

The most important virtual spaces of the Rescue Service of Gothenburg are linked to a specific physical space in the command centre in Gårda. I visited this facility in April 2010, together with a colleague from Applied IT, to meet up with one operator and two leaders of the command centre staff. I got the opportunity to see the main physical space and was also introduced to the virtual spaces of the organization. When it comes to ICT there are a number of applications that work together in a visualized information system in the command centre room. On the occasion of our visit, there were two applications running in the room, one with a sheet of numbers and text codes showing availability and location of rescue service units and one newly introduced application for showing live video sequences from the incidents (Fig. 70). The research group at Applied IT works with different issues for the implementation of this live video application for mobile phones, like accessibility, interaction design, presentation, optimization, and organizational issues. The project is yet not so focused on the spatial design or the architectural aspects of this system, even though there is an interest from the group to integrate these aspects in the project.

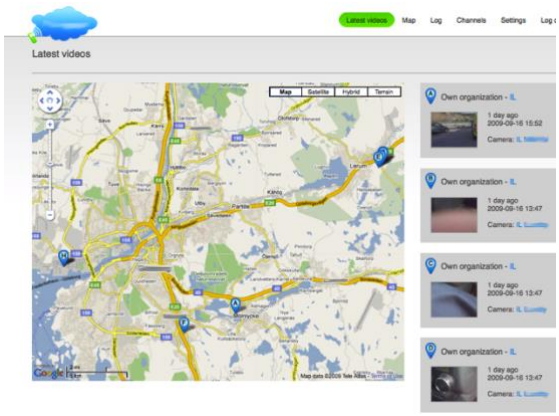


Figure 70. Web interface to the live video application. Landgren, Bergstrand, 2010

Figure 71. Screen shot of a fire incident video. Landgren, Bergstrand, 2010

The physical command centre room is situated on the second floor of the Rescue Service building and has the entrance towards a hallway with a staircase and connecting corridors to nearby staff offices. The measures of the space are about 8 by 7 meters wide and 2.5 meters to the ceiling. In the centre of the room there is a big conference room table with 10-12 chairs. There are also a couple of smaller tables along one side of the room, where one or two persons could work at each table. On all four walls there are projection areas of about 2x1.5 meters, where different digital applications can be displayed. There are also a number of white boards on the walls for manual sketching and notations. The entrance door is next to the corner in one end of the room. According to the command centre staff, there are typically 2-4 persons in the room during smaller incidents and up to 8-10 persons during major incidents. When no incident that needs special attention is at hand, the room can also be left without staff. Normally, the persons in the room sit around the main table and turn to the different walls when examining the digital projections or facing each other over the table in face-to-face discussions. All persons in the room have well defined roles of what to do and what to be responsible of.

According to my informal interviews and from investigating the room and the screens, the command centre room is considered to be a conventional physical space where a number of workstations and screens are placed. Traditionally, a room like this is designed using separate paradigms for the physical and the virtual spaces. The consequence in this particular case is that there is no coherent design for the functionality of the entire physical-virtual space where the users interact. For example, when the rescue command staff are discussing the different rescue sites, they need to turn away from each other and face the walls in order to assess the situations, which hinders effective face-to-face communication.

Conceptualisation

Seeing this space as a stage, the digital projection areas work as virtual extensions of the physical space (Fig. 72). In this physical space the projection areas work as windows into virtual space. In that sense the command centre staff are spectators that interact with the different virtual spaces where the operative staff work as actors in the real-life stage at the site of the rescue. The rescue site becomes the stage and the command centre becomes the auditorium. However, at the same time the command centre staff are actors on this merged physical-virtual stage. They have defined roles, and even costumes related to their roles, that set the conditions of the rescue drama. This case displays an important issue of the stage metaphor, namely how we define actors and spectators in relation to the stage.

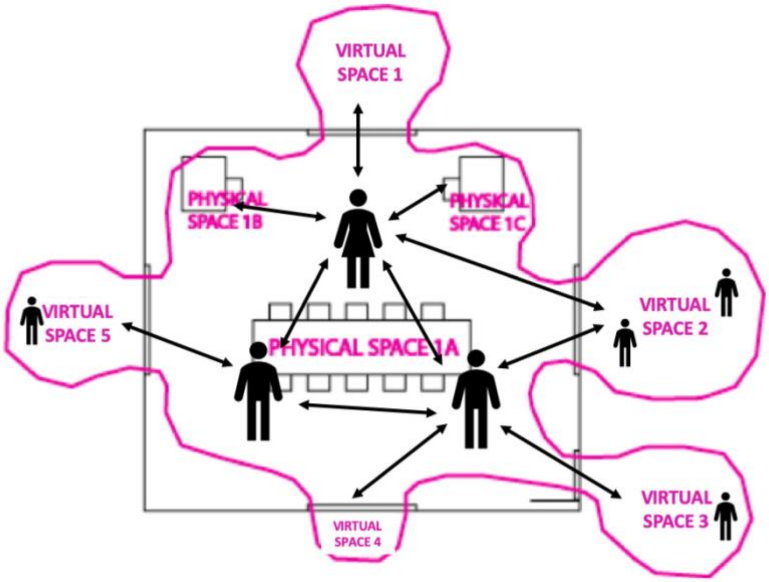


Figure 72. The Rescue Service command centre seen as a physical-virtual space

In Figure 72 above, the physical command centre room with its sub-spaces (1A-C), and the virtual spaces (1-5) that are accessed through different screens, are together seen as one unified place for interaction and decision-making. The conceptual shape of this unified place is represented as the purple 'blob' in the figure. The rescue command staff become actors on a physical-virtual stage that structurally consists of both physical and virtual spaces.

In the work with implementing live video displays in the command centre, different issues have been raised that will have to be solved in order to make the system work in the organization (Bergstrand & Landgren, 2009). An initial threshold is to make the operative staff used to the technology, so that they really use the video recording possibility when they can. In the project alternative solutions have been discussed, such as placing the cameras on rescue staff helmets. Another important issue is the ethical problem, for example that a video camera (though hidden in a mobile phone) can intrude on persons' integrity at the site of the rescue. However, one important issue that is yet to be addressed is how this live video display works as a space in relation to the command centre space. For me or anyone else who comes from the field of digital representation it is obvious that there is no "neutral" way to record, edit or display these videos. What the command centre staff gets to see in these videos is not an objective presentation of the rescue site and the events taking place. To be able to present this information via video is a profession of its own. Camera angles, time length, cuts, and framing constitute a language that tells the story of the event. My ambition here by introducing the stage metaphor is to show the importance of finding a common language of image and space that can communicate in this merged physical-virtual space. Ricoeur's idea about the arrangement, genre, and style of the "production of discourse as a work" can be seen as a means of analysis in this case.

In order to answer the first question of this case, about how the interplay between physical and virtual spaces work today, further studies will have to be made in a dialogue with the research group and the professionals. The next phase of these studies would be to answer the second question of this case, about how to actually improve the current design of the space. However, the model presented in Fig. 72 presents a promising concept for creating a common place for designing of the physical and the virtual in similar contexts.

CASE 6: VIRTUAL CULTURE HOUSE

This case is an application of the concepts of physical-virtual space, using the stage as metaphor, in the context of urban planning, citizen involvement, and the development of public knowledge institutions. The purpose is to address RQ2, using staging as method, and then conclude the results in relation to RQ3. The process of this work is a collaboration in 2012-2016 between the division of Interaction Design at Chalmers and the district of Lundby in the municipality of Göteborg. This collaboration has involved researchers at Chalmers (mainly me and Eva Eriksson), municipality staff and decision makers, design practitioners, master students in interaction design, and citizens of Lundby. This case exemplifies how interactive physical-virtual installations can form a Stage for the interaction between citizens, city planners, decision makers, designers, and cultural content. This case is also a summary of papers IV and V with discussion added in relation to the research questions (E. Eriksson & Wideström, 2015, 2014).

Aims and Background

In 2010, a proposal for a new cultural house in Lundby was approved by the Gothenburg city council, with the aim to realise the culture house in about 8-10 years. The concept builds on the idea that cultural activities and expressions are important for the life quality of the citizens, and that a culture house is a service that the district Lundby should provide. The intended content of the culture house is a library, exhibition areas, a multi-purpose hall for lectures, cinema, concert and theatre, rehearsal rooms, meeting rooms, workshops, a café, and possibly other facilities. The activities are meant to be run by three different actors; the district of Lundby, other cultural institutions of Gothenburg, and commercial actors. The vision is that the content and design of the cultural house is developed in close collaboration with the citizens of Lundby, making it flexible and updated for the different and ever-changing activities of the local communities.

In the proposal for the culture house, user involvement is emphasized, both regarding the ongoing planning process and for the future management. The overall goal is that the culture house will be a well-known meeting point and cultural center, both for local citizens and for visitors to Gothenburg. The proposal also points out that the culture house will be built using the latest technology, also involving VR technology, for sustainability reasons but also for the flexibility and interactivity of the physical space. In 2011, a physical prototype space for the culture house, called Culture Warehouse, was established. The building is a huge and empty warehouse situated in a void urban space, where different artists have used the space for performances and exhibitions. The purpose of this temporary physical space is to give room to cultural activities that contribute to the citizens' creativity in projects that have low or no budget.

One of the initial steps in developing the culture house was to define a Virtual Culture House. This had three aligning purposes; to realise a set of virtual spaces where cultural activities and expressions can take place and later complement the physical culture house, to inform and support the ongoing design process of the culture house, and also to promote it to the citizens.

Design Problem

The Lundby council has an ambition to merge the cultural activities that take place in physical and virtual space. They want to encourage the citizens to contribute both physically and digitally to the content and identity of the culture house. However, in the initiation of the culture house project there was no unifying concept for how these contributions could be made and where they could take place. Neither traditional public hearings nor social media interaction had led to good quality input from the citizens.

In our initial discussions with Lundby, they had little insight and understanding of this design problem. Was there even a problem? They had an idea to just make a homepage and an app that showed the cultural activities. As researchers and practitioners in interaction design, we (Eva Eriksson and I) first had to aquire the context of the culture house project from Lundby, and then explain to them the complex conditions of this project. We convinced them that a communicative and creative development process that involves interaction between different user groups through different media, needs to be analysed in relation to co-existing and dependent spaces. As formulated in the Four Space Model (E. Eriksson, 2011) interactive activities and artifacts can be understood in terms of the physical space, the digital space, the interaction space, and the social space.

Our approach to this design problem was to develop "exploratory interventions" as method for stakeholders to stimulate engagement from the citizens around the planning and development of this new cultural house. These exploratory interventions were intended as interactive physical-virtual installations, providing a stage for the interaction between the different stakeholders of the culture house project.

Results

The outcome was twelve different prototypes, developed by master students in interaction design, all tested in the municipality. Based on analysis from these experiments, a model describing six categories of methods of exploratory interventions mixing the virtual and the physical in order to stimulate involvement in the development of public knowledge institutions was presented (E. Eriksson & Wideström, 2014).

A classification was made in six different categories A-F, which differ in purpose, concept and method (Table 4). A common concept for all six classes of methods presented is that they a) address the co-existence of physical and virtual spaces and b) stage the interaction between different actors relevant for the development of the design process (citizens, stakeholders, planners, decision makers, and designers).

The prototypes were developed by groups of Master students in interaction design at Chalmers, in close co-operation with the stakeholders in Lundby. The classification is summarised in this table:

Class	Interface	Purpose	Target
A	Visitors / culture house	Create new experiences	Culture house visitors
B	Citizens / culture activities	Content and community building	Local citizens
C	Citizens / culture house program	Inform design process	Local citizens
D	Visitors / content	Inform citizens about content	Culture house visitors
E	Creators / citizens	Staging cultural content	Local citizens
F	Visitors / visitors	Sharing experiences and community building	Culture house visitors

Table 4. Model of categories for exploratory interventions

A) INTERACTIVE ART INTERVENTIONS

Purpose: To evoke the experience of presence in, and interacting with, the physical public space before it is realised. The intention is to create interest and expectations from the citizens.
Concept: To create an interface between visitors and the physical culture house, in order to make visitors' presence in public space matter.
Method: To display an interactive art installation, related to the context of the intended public space that can give the users an experience of interactivity and presence.
Examples: The ChimeCloud (Fig. 73 a) is a physical-virtual installation that creates sounds from people passing by. In the E-Motion Wall exhibit, people passing by leave visual traces.

Figure 73. a) The ChimeCloud

b) The E-Motion Wall

B) VIRTUAL MOBILE SPACES

Purpose: To strengthen and develop local cultural networks and communities.
Concept: To create an interface between citizens and local culture activities.
Method: To introduce virtual spaces that is filled with cultural content, as activities and/or results of cultural activities.
Examples: The Virtual Rooms project (Fig. 74 a) and the Culture House App (Fig. 74 b) form activity-based virtual spaces for cultural content.

Figure 74. a) Virtual Rooms

b) Culture House App

C) DESIGN PROCESS CONTRIBUTIONS

Purpose: To inform the design process
Concept: To create an interface between citizens and the programme of the cultural house.
Method: Through data gathering
Examples: The MCN project (Fig. 75) informs the programme of the cultural house.

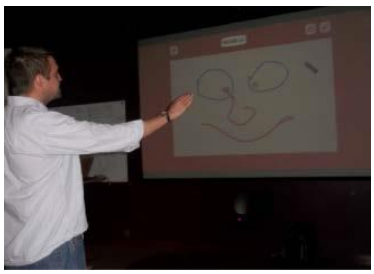


Figure 75. a) MCN web

b) MCN installation

D) EDUTAINMENT INSTALLATIONS

Purpose: To inform citizens of the content
Concept: To create an interface between visitors and content
Method: Interactive media installations
Examples: Live Tree (Fig. 76 a) is an interactive physical-virtual exhibit that displays the ongoing activities in the physical culture house. The Gate (Fig. 76 b) is a metaphorical gateway to a virtual space for cultural content.

Figure 76. a) Live Tree

b) The Gate

E) INTERFACE BETWEEN CREATOR AND AUDIENCE

Purpose: Stage artistic work and content related to culture
Concept: To create an interface between creators of content and citizens
Method: To stage the space framing of the content for exploration and experience
Examples: Invisible Showroom (Fig. 77 a) and Virtual Window (Fig. 77 b) are virtual spaces for the display of artistic work and interaction between citizens and artists.

Figure 77. a) Invisible Showroom

b) Virtual Window

F) SOCIAL INSTALLATIONS

Purpose: To share experiences and support community building
Concept: To create an interface between visitors
Method: To stage interventions, installations and spaces that trigger social interaction through exploration
Examples: Tile voting (Fig. 78 a) is a physical-virtual installation where visitors to the culture house can influence the mood of the environment (music, lighting etc.). Backa Orchestra is a physical-virtual space for jamming and having coffee.

Figure 78. a) Tile Voting

b) Backa Orchestra

The Virtual Culture House

After this categorization of the exploratory interventions, we started developing The Virtual Culture House. In this work we pursued our ambition of finding new ways to stimulate a dialogue with citizens in the development of public buildings and spaces. The purpose of engaging in dialogue with the citizens is firstly to make the public aware of the project in order to create interest, and secondly, about introducing a process, where the citizens are invited to take part of and inform the architectural program and planning processes, which finally can provide stakeholders with material for decision making. These processes are quite complex in the way it spans over time and involves decisions and input on many levels. Our strategy for this Virtual Culture House was to create a *Stage* where all these activities and processes could take place in one common virtual space.

User involvement is common in e.g. interaction design, but has in recent years become an important factor also in architecture and urban development. Most common methods used today are virtual models, questionnaires, physical architectural models, or public hearings, that give little input to the process. It can be argued that the introduction of web 2.0 services and social media tools has opened up for the possibility for exchanging perspective and actually involving citizens for consultation, just as e.g. the public hearings. Though, too often these consultative initiatives such as public hearings are more used for statistical purposes, rather than actually have a real effect on the process.

When stakeholder involvement is incorporated into large planning processes, power can be redistributed through negotiation, and involvement lead to agreements. This requires that the different stakeholders have methods, tools and inspiration in order to be curious, and be able to do new types of explorations and interventions to engage citizens, decision makers and contributors, both before and after the program development. This will eventually provide material to support the decision-making process. In AELIA (short for Attention–Experiences–Learning–Influence-Action), which is a strategic process model developed for user involvement and how to create a constructive active dialogue in urban development processes, it is not only stressed that getting the Attention of citizens, keeping them interested through novel Experiences, building capacity by introducing an element of Learning, giving the citizens Influence is important, but also that supporting Action by relevant actors is important to consider (Delman & Nielsen, 2009). But for this Action to happen, we need to develop new methods and tools.

At this phase of the project, we applied our previously developed model for stakeholder involvement in a large public project development project, aiming at building a new cultural house. We investigated how different relevant stakeholders can be provided with tools and methods in order to participate in the planning and implementation process (E. Eriksson & Wideström, 2015). The contribution of this work was twofold; the description of a dialogue tool, a virtual platform complemented with physical staging, as well as a discussion on the importance of involving a variety of different stakeholders in the process, both in planning and implementation, and how this can be achieved.

The outcome of this second part of the project was a web-based portal defined as the Virtual Culture house. The portal has replaced all the scattered communications and information channels that the municipality has used previously in order to communicate with the inhabitants. The focus of the development of the Virtual Culture house has firstly been to put focus on gathering all different types of cultural activities in one place, and secondly to get the different actors engaged in contributing to the portal. The result demonstrate what activities, needs, groups and communities there are in the municipality, which ultimately will guide the planners in what the needs are for the future physical culture house. The Virtual Culture House is strongly connected to the site of the future physical Culture House and its surroundings, with the presentations of the Virtual Culture House overlaying a background of videos of the physical environment (Fig. 79).

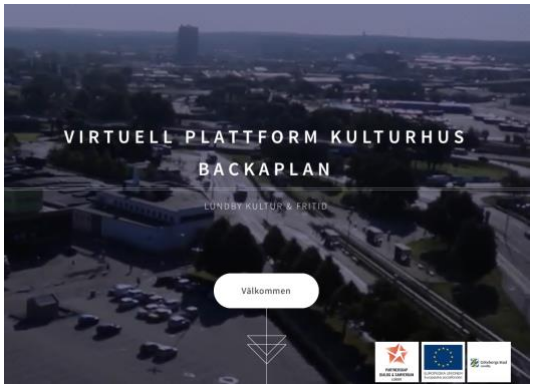


Figure 79. The entrance of the Virtual Platform Backaplan. October 2014.

The Virtual Culture House is a web-based platform that consists of a database back-end and a graphical web interface front-end. The content of the database is created both by the editors of the municipality and the visitors to (co-creators of) the Virtual Culture House. Conceptually, the database works as a central hub where content can be created via the external interfaces of different physical devices and installations. A range of applications can be connected to the database in order to create and use the data in different forms, such as location-based apps, photo apps, and so forth. Traditionally, material from culture events arranged by the municipality is not easily accessible in a format that can be used by other applications. In the way this system is organised, all material created in cultural activities can be used and accessed for the purposes of the Virtual Culture House, that is; to be a place for cultural activities, to inform the design process, to develop an identity for the culture house, and to promote it to the citizens.

The front-end of the Virtual Culture House is a website, where the content is organised in "Events", "Projects", and "Rooms". The "Events" promote different cultural events that are arranged both by the municipality and other organizations of the local community, such as theatre plays, concerts and exhibitions. The "Projects" present the different local cultural organizations that are supported by the municipality, such as the Skateboard Park group and the Arts & Crafts group. The "Rooms" are collections of cultural content that are presented as thematic virtual exhibitions, where each room can be a collection of texts, images, videos and sound files (Fig 80). In addition to this, users of the Virtual Culture House can submit their own contributions in different media forms and also post messages with their opinions about a future physical culture house. These contributions can then be seen by other visitors in the different rooms.

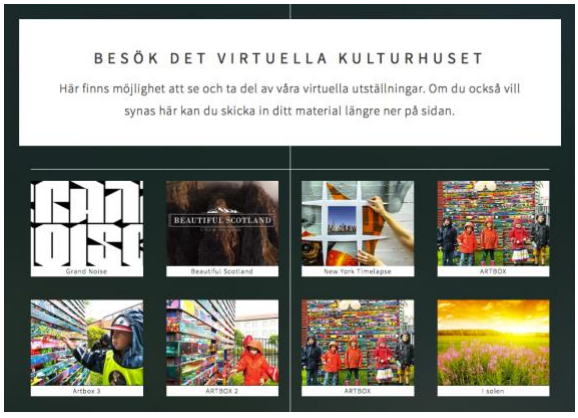


Figure 80. Rooms created in the Virtual Culture House. October 2014.

Connected to this website there are external applications for creative and playful ways of informing the design process of a future physical culture house (Fig. 81). The example in Figure 81 is an application where anyone can design the culture house, and define how many percentages should be the library, garden, art exhibitions, concerts hall, etc. This means that the content of the Virtual Culture House is built up from the activities that take place in the local community, both physically and through digital media. Parts of these activities are staged by Lundby and others are self-motivated.

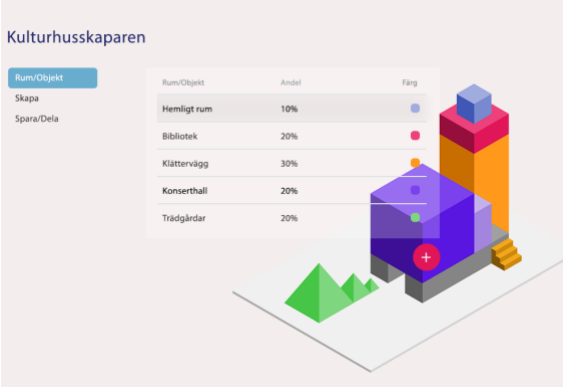


Figure 81. Culture House Creator, where users create their own proposals. October 2014.

The Virtual Culture House was launched in 2014, and has played an important role in the planning process of the physical culture house and for engaging the citizens. In relation to this classification of tools and methods, the aim of the Virtual Culture House is to incorporate all six categories of exploratory interventions in one platform. The different activities that take place in the development process of the physical culture house belong to different categories but are all linked to a common portal. The Virtual Culture House has focused on categories B, C, and E, which target the local citizens. The purposes of these categories are content and community building, informing the design process, and staging cultural content.

This case demonstrates how different forms of activities in virtual and physical space can be staged to support the stakeholder involvement to move from single-user to multi-user experiences, from individual design to social design, from closed to extendable and open institutions, from regulated designs to evolving designs, and from systems and processes designed merely to act as information providers to dialogical systems. In the model, the visitors of the institution, the citizens of the city, the contributors to the knowledge institutions activities and programs are considered on equal foot with the officials behind the institutions, and stage participatory activities in order to stimulate self-organization behaviour. The Virtual Culture House changes the roles of the traditional process where an institution is defined, to a dialogical process where the activities will form the building.

We have not yet seen the final result of this process, or the final implementation of the culture house, but through the process of developing the virtual manifestation of the culture house to come, the mindset of the officials has changed and an increased openness to experiment with different tools, methods and activities is now highly appreciated and a part of their back bone understanding of the development process. The virtual platform also provides the contributors with a new communication channel both with officials as well as citizens and other contributors, which has increased motivation to stage activities, self-organised or not. In addition to this, we propose to complement the virtual platform with different physical manifestations and interventions, inspired from the model in the first part of the project, in order to inform the building and the plan.

Staging the Interaction

The contribution of the Virtual Culture House is to suggest new ways of complementing the traditional architectural visualizations and public hearings for involving citizens in the development process of public knowledge institutions. These new methods aim to support the individual needs of the different actors and needs in every new planning process. The study is based on experiences from a case where 1) a virtual platform has been developed as a dialogue tool between stakeholders in order to create attention, engage citizens and inform the design process, 2) a model for exploratory interventions that intertwine the virtual and the physical in order to stimulate citizen engagement in the development of public knowledge institutions have been proposed.

The Virtual Culture House is a dynamic space for the dialogue between different stakeholders in the development process of the physical culture house. It supports both staged and self-motivated activities that take place in both physical and virtual space. The close relations between the Virtual Culture House as virtual space and the local community as physical space, creates an activity-based physical-virtual space that works as a stage for the development process of the physical culture house. The result of this process will therefore not only be a new physical structure in Lundby but also a gestalt of cultural ideas and expressions that shapes the identity of the future culture house. This also means that the Virtual Culture House is more than a tool in the development process, but rather a place for cultural ideas and expressions with its own raison d'etre.

Staging in this case is used effectively to connect virtual and physical spaces. The approach to stage the physical-virtual exhibits resulted in an interactive performance for making the exploratory interventions. In the second phase of the project, where the virtual culture house is developed, the stage is formed as a physical-virtual structure that can provide a place for the citizens to become both actors, artists, and audience. In conclusion, staging presents as a fruitful method for forming a common place for connecting physical and virtual spaces.

CASE 7: INTERACTIVE SCIENCE CENTER

This case highlights the relations between physical and virtual spaces in science centers. These relations are investigated by staging the interaction between visitors to the science center and the science content, using physical-virtual spaces. The aim is to strengthen the statements made in the previous case, by applying staging as a method to support conceptualization and implementation of the relations between physical and virtual space, in a different context.

Designing for science center exhibitions is a challenging task that exposes important design issues and puts concepts and methods to the test. Science center exhibits are typically highly interactive, involve a wide range of target groups, have a specific purpose of being educational and engaging, and set requirements for robustness and ethics. The exhibits open up for different modes of embodied interaction, where users can participate and collaborate in different forms and degrees, and where digital and physical design materials and spaces merge. Science center also works as a stage for transdisciplinarity, where natural science meets arts and humanities. This case investigates interaction in science center exhibits, focusing on the relations between physical and virtual spaces (Wideström, 2020).

Background

Architectural design and interaction design merge as our physical and digital spaces become inter-dependant and co-existing (McCullough, 2005). The forms of computer technology are changing and becoming part of our physical space, and as computation is integrated in physical space, interaction designers are increasingly working with spatial digital artifacts (Dourish, 2004). With the development of new technology and "smart" systems, interaction design becomes an indispensable dynamic in life (Liu & Zhang, 2019). Adding spatial aspects, interaction design brings the interface out into the room and expands the role of the interaction designer to develop structures and form as well as compose situations for its users (E. Eriksson, 2011). While architects are creating spaces from building material, interaction designers are creating situations in both physical and digital space using IT as the primary design material. IT could be considered as a non-physical and non-spatial design material. However, when designing spatial interfaces, physical materials come into play and designers must understand how the properties of IT relate to spatial properties and boundaries. When it comes to designing virtual spaces, IT becomes a highly spatial design material. Novel concepts, such as Augmented Reality, Mixed Reality and Substitutional Reality (Simeone et al., 2015) show that digitally produced virtual spaces and actual physical spaces can merge.

Public knowledge institutions, such as museums and science centers, are transforming the way the scientific and artistic content is displayed and communicated. New media give new possibilities of interaction and experience, where spatial aspects need to be addressed. Virtual spaces complement and expand the physical spaces of science centers, both in the design process and in the realised exhibitions (E. Eriksson & Wideström, 2015, 2014). The merge of physical and virtual spaces is particularly interesting to study in science center settings, since the science center is a highly interactive environment, dedicated for learning activities, and with a wide spectrum of user groups. In a science center, there is also a wide range of possibilities for the scientific content to be displayed and interacted with. The relation between physical and virtual space is contextual and depending on other relations. In the case of science center exhibitions, this context is formed by the scientific content, the staging of this content and the users' interaction with the content and each other. Theoretical design research on science centers, summarised in the DEX framework (Ocampo-Agudelo et al., 2017), suggests that the visitor experience in a science center is based on five building blocks; physical, institutional, personal, relational, and social.

Universeum is Scandinavia's largest science center, with more than 500.000 visitors every year. It includes an aquarium and terrarium as well as a rainforest with tropical animals.

The science center has also exhibitions about space, health, technology, and more. Universeum has a strong pedagogical profile, with over 60.000 school children visiting yearly. These school visits are related to the curricula on different levels of the education regarding natural sciences. Universeum's mission is to make young people interested in and to teach them about technology and science and inspire them to pursue a career within those fields. Universeum also has a mission from the city of Gothenburg to be an attractive place to visit for citizens and tourists (Universeum, 2015). The variety of audiences and ways of interaction present a background for setting up different types of exhibits. In order to facilitate conceptualisation and communication, a classification framework is proposed.

Method

The methodology for investigating the interaction is *research by design*. New knowledge in the intended domain is created through design work in the related context. Here the methodology is balanced between inspiration-based design research and information-based design research (Sanders, 2005), where knowledge is built upon experimentation in combination with investigation. As such, the methodology relies on the designing of prototypes as a generator of knowledge (Stappers, 2007). Unlike the theoretical design research approach, this research has been conducted through design work. The focus has been on the relational building block, as presented in the DEX framework, giving the interaction between users and exhibits a central role.

My role in this case has been to manage a project course at the Interaction Design and Technology master program at Chalmers. This project course has been run in collaboration with external partners, where the students have developed their concepts and prototypes in real-like conditions. The pedagogy of this course has been inspired and developed from the *Authentic and Negotiated Assessment* model (T. Eriksson & Wideström, 2006). In 2016 I initiated a collaboration with Universeum Science Center in Göteborg for the project course, that led to a period of four consecutive years with Universeum as the external partner. During 2016-2019 the students have worked with different themes but with the same context of the science center. In addition to this role, I have also participated in Universeum's development of new concepts for exhibitions as a part-time co-worker in the project management staff. These two roles have given me good insight in and control over the interaction design project themes.

During 2016-2019, 45 prototypes of exhibits have been developed, in a collaboration between Universeum and researchers, teachers and students at the Interaction Design & Technology master's program. These prototypes have been displayed as interactive installations and tested with hundreds of visitors each, and they have been an important part of the innovation process at this science center. Some of the prototypes have been developed into actual exhibits and others have worked as inspiration for future development. My contribution has been to initiate the projects, developing five themes in collaboration with Universeum and then supervising and leading the 10-13 projects during the 8 weeks' project periods. The project themes have been:

2016 – The Interactive Science Center:
Projects with focus on the interaction between visitors and natural science
2017 – The Participatory Universeum:
Projects with focus on user participation and co-creation of content
2017 – The Virtual Universeum:
Projects with focus on interaction in virtual space
2018 – New Technology:
Projects with focus on interaction with sensor technology, AI, and VR/AR
2019 – Showing the Invisible:
Projects with focus on interaction with invisible phenomena

Physical and Virtual spaces

The relations between physical and virtual space have been central in all of these projects. The projects of 2016 had in common that they targeted the learning outcome of natural science in the science center. The projects elaborated on popularizing science, using different techniques and concepts for visualization. Here virtual space was explored as interface to scientific data, as for example in the *Interactive Mirror,* where the users see the skeleton inside their own body (or so it seems) and move and play around in front of the mirror (Fig 82 a). The 'participatory' theme of 2017 investigated how the users could participate in the co-creation of content in the science center. Here virtual spaces played an important role of creating dynamic and flexible spaces, where the content could be explicitly edited or implicitly affected by the visitors' interactions. The *Lightspeed Bike Space Travel* project illustrates one participatory approach, where users were pedaling through the solar system on a bike, physically on a trainer and virtually in lightspeed in space (Fig 82 b). The other project theme of 2017 focused on the virtual science center. Where could it be? What could it be? How could it be represented? Exhibits of this theme resulted in VR environments and AR applications, but also included social media as part of the projects. Here virtual spaces contributed to the before-during-after perspective of the visit to Universeum, showcasing how virtual spaces can expand the physical spaces of the science center. Other projects focused on the experience of virtual space, such in the *Mission Mars* exhibit, where one user was pursuing a mission in a virtual mars landscape, while another user was controlling the mars vehicle from a control center on earth (Fig 82 c).

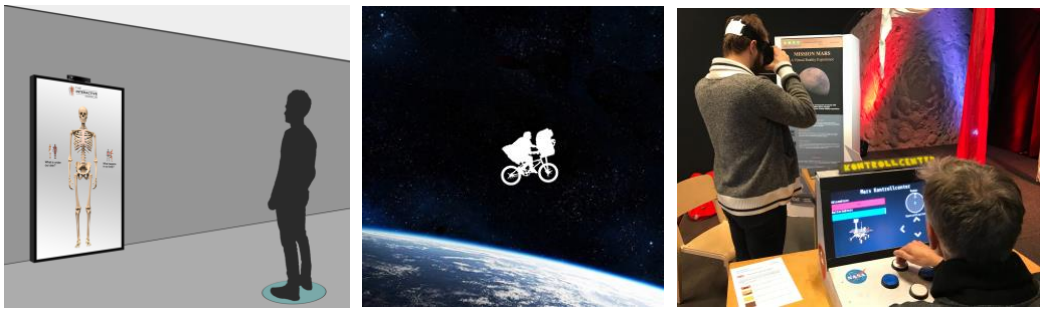


Figure 82. a) Interactive Mirror, 2016. b) Lightspeed Bike Space Travel c). Mission Mars

The 'new technology' projects of 2018 explored computer technology and IT as design material, focusing on AR, VR, AI, and sensor technology. Here the virtual spaces were studied through Virtual Reality as an interface, also including the relations to physical space of the surrounding environment and the physical actors/users in the embodied interaction. The *VR Escape* project had a meta-technological focus, teaching users about VR technology in a collaborative VR game. The interesting twist was that only one user was trapped in the virtual escape room, while the other 3-4 persons were "outside" in the physical space, watching and helping the trapped person to escape. So here the collaboration tied the physical and virtual space together in an interesting way (Fig. 83 a-b). In 2019, the purpose of the projects was to make invisible phenomena visible and tangible. Here virtual spaces played a central role in "showing the invisible". One of the main purposes of this theme was to let the visitors experience phenomena in cosmology and astronomy, such as in the *Twinstar Supernova*. In this exhibit, two users collaborate in an interactive game-like physical-virtual environment, where the interaction with the two stars are embodied by standing on balance boards (Fig 83 c).

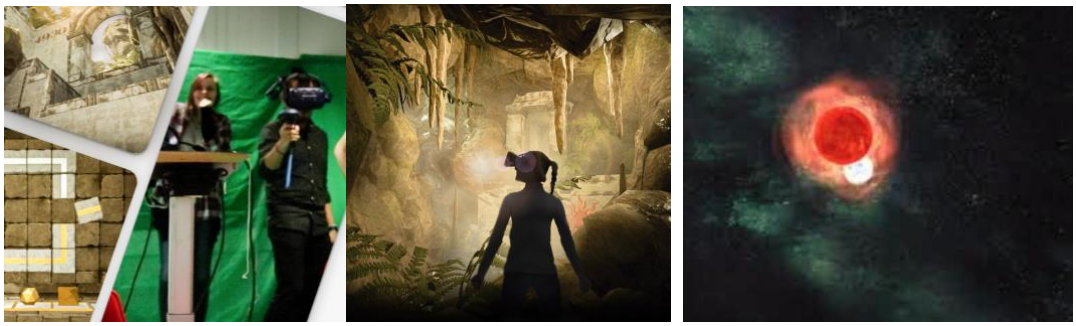


Figure 83. a) Virtual Escape b) Virtual Escape c) Twinstar Supernova

All of these projects show how interdependent the physical and virtual spaces are. In the science center context, there are no virtual spaces that do not take place also in physical space. Somewhere and somehow, the virtual space has to manifest in physical space as screens and VR devices, but also accompanied by tables, boards, posters and other material. The user interaction happens in a physical-virtual space, where some exhibits focus more on interaction with the virtual and others with the physical. From this user interaction perspective, the exhibits can therefore be placed on a continuum from physical to virtual. The level of virtuality concerns how much of the interaction that takes place in the actual physical space vs in the potential virtual space. When one interacts with a computer-generated virtual space, the screen displays an image that depends on physical interactions happening between the actor (user) and the computer, at the level of hardware. The virtual space is nowhere in actuality of the outside world, but is nonetheless real and can be interacted with as it is present in our cognition. Simultaneously, the actor is present in a physical space, where the screen works as a window into the virtual world. An actor who interacts with both a physical and a virtual space simultaneously, can be said to be present in a physical-virtual space (Fig 84).

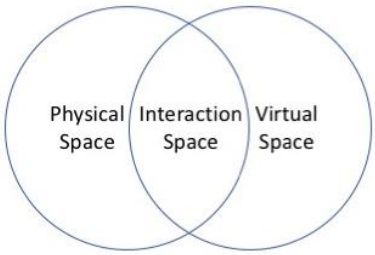


Figure 84. Interaction Space as Physical-Virtual Space

A physical exhibit at a science center allows hands-on interaction, typically with levers, wheels, building blocks, and sometimes even sand or water. Sometimes the installation lacks interactivity, but is rather a poster, a sculpture or a display of objects. A virtual space of a science center might be a visualization or virtualization of some kind. It can also be a computer-based simulation, an artificial intelligence or a computer game. The website of the science center is also a space for the virtual science center. The social media space of a science center is also a virtual space that exists, partly out of control for the management. Some exhibits use a combination of physical and virtual spaces and elements, such as physical landscapes projected with a digital augmenting overlay.

Virtual space is seen as separate from physical space in an architectural (structural) sense, but the two worlds co-exist in an interdependent relation. An actor/user/observer can experience presence in both physical and virtual space simultaneously, through an interaction space that involves both physical and virtual space, meaning that this actor interacts in physical-virtual space through an embodied interaction. Also, using augmented and mixed

reality technologies can create a physical-virtual space for interactive learning (Cuendet et al., 2013).

The more virtual exhibits highlight the possibility to "show the invisible", and let users see and interact with phenomena that cannot be seen with our human senses in the actual world. In the *InteractiveMirror* installation, the users can see the skeleton inside their own body (or so it seems) and move and play around in front of the mirror. This exploratory approach is typical for exhibits that take place in virtual space. The virtual exhibits can also be in the form of games, like in the *OceanCleanUp* or the *RadiationPlatformer* projects. Here the gamification is meant to evoke a higher motivation for the user to experience and learn about the targeted scientific content. An advantage with virtual installations is that they are mobile and can be moved and showcased outside the physical space of the science center. Some virtual science projects can also be adapted for the Universeum website, connecting the experience to before and after the visit.

The more physical and hands-on installations take advantage of the sense of haptic touch and tactile touch, and also other senses than vision. In contrast to the virtual space, the physical space has scale, gravity and materiality. In the *WindiCity* project, users build their own physical windmills that are compared in relation to the amount of electricity generated (Fig. 85 a). In the *WaveLab* setup, users interact with sound waves, vibrations and resonance (Fig. 85 b). In the *CyborgBox*, users are blindfolded and equipped with proximity sensors that replace their vision and help them walk through a labyrinth in analogy with the senses of a bat. In these exhibits the embodied interaction gives feedback mainly in physical space and not through a display or other digital interface.

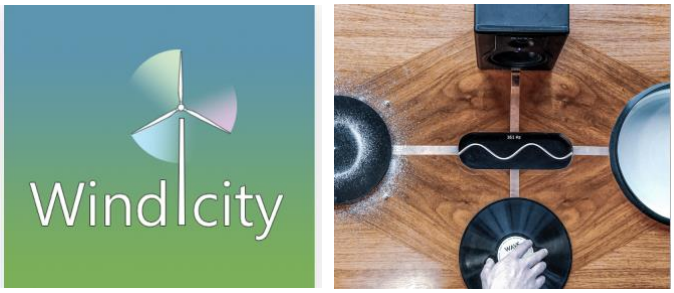


Figure 85. a) WindiCity b) Wave Lab

Staging the Interaction

Regarding the relation between physical and virtual space, the virtual exhibits can work as "windows" or "doors" into other worlds, seen from the physical environment. In these virtual spaces new agreements and experiences can be made. The user can see invisible phenomena such as temperature or electromagnetic fields, interact with quantum mechanics, or travel to other galaxies. However, the virtual spaces of the science center need to be related to the physical context. The understanding of a virtual installation depends on the surrounding physical space, and the user experience is formed in a physical-virtual interaction space.

The science center is an excellent place for staging the interaction between actors and spaces, and between physical and virtual spaces. The spatial properties and relations are highlighted on this stage, forming a seeing place – a theatre for exploring natural science.

6. Contribution, Discussion, and Conclusion

Research Questions Revisited

The seven cases and the seven papers of this thesis are related to my main research questions at different levels and degrees. This discussion will turn the matrix, addressing each question first and then relating the cases and papers to the respective question.

RQ1: What are the relations between Physical and Virtual Space?

RQ2: How do metaphors support conceptualization and implementation of the relations between Physical and Virtual Space?

RQ3: How can a common Place for Physical and Virtual Spaces be formed in the practice of design?

RQ1: The Relations Between Physical and Virtual Space

So, what are the relations between physical and virtual space? There are fundamental differences between virtual and physical spaces, in the expectations we have, agreements that are made, and the language we use. The use of touch and the idea of embodied interaction have brought virtual and physical objects closer, but when it comes to spaces the physical-virtual divide still exists. In cases of physical-virtual spaces like the ones I exemplify here, this divide can be an obstacle for both creation and understanding. However, when we analyse the relations between physical and virtual space, we can see that they are highly interdependent in the way that:

a) virtual space is used as a tool to create physical space, which implies that experience of physical space depends on expectations created in virtual space,
b) also the opposite applies, that we use our conceptions of physical space when we interpret virtual space, and
c) the coexistence of physical and virtual space has become common in everyday situations in our public institutions, homes and work environments.

A semiotic discussion on physical and virtual space shows that this mutual dependence creates unification in itself. Using structural semiotics, we can see that new signs are produced in the intersection between physical and virtual space. Taking a non-structural stance in semiotics, it can be argued that there is no physical-virtual divide at all. If there is, the constant use of physical-virtual spaces in our everyday life creates more and more traces of interpretation of one space into the other, so that reference and origin in the sign production is lost in a never-ending game.

In the *Block-Box-Prism-Wedge* case, the focus is on architectural concepts and how physical and virtual representations contribute to the development of the design process and the realised spaces, both physical and virtual. The user in this case is the designing architect, that drives the process forward, back and forth between different representations. The case shows that physical and virtual spaces have different properties; the physical representations and spaces have scale and materiality, while virtual spaces lack scale and materiality. In spite of those fundamental differences, the physical and virtual can come together in a unified gestalt that represents the architectural intentions. Also, there are traces from one representation to the other in the chain that connects the physical and the virtual. This case also highlights the interplay between the potentiality of virtual spaces and the actuality of physical spaces. Virtual space both asks questions to the actual and answers questions from the actual, via the architect

in a communicative process. The virtual-physical hierarchy shows to be arbitrary so that virtual space can be seen as an interface to physical space and vice versa. Altogether, this case contributes to answering RQ1 on all levels of abstraction.

The case of *Physical and Virtual Spaces for Visual Arts* deals with these relations in a different way. It focuses on the act of looking at visual art, together with a semiotics analysis on the four spaces. Meaning is created in the sign process with the viewer of the artwork as observer. The analysis shows that there is a strong interplay between physical and virtual, having an open dialogue and mutual gain. In the relation between physical and virtual space it is not given that the virtual space is a digital version of the physical. The virtual spaces also have qualities that are transferred to the physical spaces, such as flexibility and interactivity. Interacting in a virtual-physical world, the reference for understanding is mutually interdependent.

In situations like the ones exemplified in Cases 3-5, we can see that there is no thought-through unifying idea that includes both physical and virtual spaces. In Case 3, *Baltic sea forum*, the lack of a joining concept created alienation between the actors and the different parts of the science centre they were planning. Case 4, *Museum of Natural History*, is more of a presentation of a typical situation, where the introduction of additional virtual spaces in the physical spaces is problematic. My contribution here as a designer is making a list of some implementable changes that could open up an interplay between the physical and the virtual. In Case 5, *Emergency Response Center*, the stage was already at hand as a physical-virtual space, however not designed as a whole architectural space. This case is interesting as an example of how virtual spaces are not so well integrated in the physical environment.

Cases 4 and 5 illustrate the relation that virtual space has to physical space in respect to extension and overlay, contributing to the answers to RQ1. The *Museum of Natural History* case explores the potentiality of virtual space, even in a somewhat 'reluctant' environment as this museum. Here, virtual space can be seen as an overlay on the exiting physical space. The users of this case are both the visitors and the staff of the museum. The visitors were using social media to expand the physical museum in virtual space (without influence from the museum staff) but there was not much input from the virtual to the physical. My analysis is that virtual spaces here could be added as an additional layer to the museum, in such as virtual backdrops and dioramas. In the *Emergency Response Center* case, the workplace for the leaders and operators consists of a physical space (control center) that is expanded by a set of virtual spaces (representing the rescue sites). This case demonstrates the extension capacity of virtual spaces, and how the connections between the virtual and physical can be made. The 'blob' shaped physical-virtual space becomes a model of thought for the understanding of this complex place.

Cases 6 (regarding the *Virtual Culture House* in combination with paper IV and V) and 7 (regarding the *Interactive Science Center* in combination with paper VII) illustrate the capacity virtual space holds for making the impossible possible. Virtual is here 'more than real' in different ways. In the case of the *Virtual Culture House*, virtual spaces are used for solving the problem of evoking and encouraging participation and interaction, something that had not been solved in the physical spaces of the community. Here, virtual space is used to inform physical space, but also to create identity in a not yet built environment. The *Interactive Science Center* case shows how virtual spaces can expand and augment the physical spaces and our perception. The more virtual exhibits highlight the possibility to "show the invisible", and let users see and interact with phenomena that cannot be seen with our human senses in the actual world.

Learning is an interesting topic for the relations between physical and virtual space that are explored in RQ1. We want to establish how knowledge is transferred and applicable from virtual to physical space and vice versa. Can we actually learn something in VR that is useful in real life? And the other way around? This complex question is investigated in paper

I, *The collaborative cube puzzle: a comparison of virtual and real environments*, showing that in that particular case, users could actually make more use of practicing in the 'real' setting for applying in the virtual than the reverse. It was confirmed, though, that experience from one setting had influence on performance in the other, in both directions. However, this can be assumed to be quite contextual. In an attempt to address the particularity of this test, we performed a more elaborate study in paper III, *Immersiveness and Symmetry in Copresent Scenarios*, resulting in the conclusion that both immersion and symmetry of VR interfaces are important for performance as well as for collaboration.

VR as an embodied medium is discussed throughout the thesis and studied in paper II, *The Pelvis as Physical Centre in Virtual Environments*. This study explores how the human body relates to the concepts of motion and space. Normally, the eyes as physical control point are used as the human's bodily centre in virtual space, leaving the rest of the limbs as a mere 'tripod' for the 'camera' in the scene. Here we found that the body centre of mass should instead be used as physical center to create the necessary connection between humans and virtual space. However not applicable for all VR interfaces, it points at the discrepancy between physical body and virtual space in many of the settings and devices that we use today.

RQ2: How Metaphors Support the Relations Between Physical and Virtual Space

Metaphor is a powerful way to change meaning, transfer meaning from one context to another, and to unify different conceptual domains. Extending the use of metaphor in language to include not only written text but also architectural and virtual space opens up possibilities to work with spatial expressions as important vehicles of meaning. With introducing the stage as conceptual metaphor I create such an engine for the connection between physical and virtual space. Another choice of metaphor might also be fruitful, but my argumentation and examples show that the stage metaphor has many layers and dimensions that fit into both physical and virtual space, linking the two together. As conceptual metaphor, 'stage' is powerful and leads to connotations where other subordinate metaphors appear; actor, audience, role, line, show, drama, curtain, décor, props, spotlights, behind the scenes etc. Making use of the stage metaphor also implies the possibility to make use of these other metaphors. I suggest using stage as a place for agreement, attention, and experience, where people have different roles, interacting with physical and virtual spaces. I also suggest that the process of stage design can contribute to the creation of new and meaningful physical-virtual spaces.

A method to facilitate connections between physical and virtual space is the development of common concepts and metaphors. This idea, to use metaphor for general mappings across conceptual domains, is supported by Lakoff and other cognitive linguistics. Metaphor is not only about written text. As it turns out, abstract concepts like space, time, states, change, causation, and purpose also turn out to be metaphorical. Here we can see the connection to virtual space that works as a 'stage' for cross-domain mappings between for example optics, computer graphics, architecture, art, interaction design, cognitive science, semiotics, hermeneutics, and social science. The metaphor of 'stage' could therefore support communication of ideas from multiple domains.

The *Baltic Sea Forum* case shows how a project group can see virtual and physical spaces as two separate worlds, and how these worlds can come together on one unifying stage, creating a coherent experience for the actors/users. It was clear that initially the project group had different preconceptions and made different agreements with the planned physical vs virtual spaces. There were already connections between the physical and the virtual in terms of content, science topics, and target groups, but these relations could not be seen in the perceived physical/virtual divide. It was with the introduction of the stage and the surface metaphors that the people involved could conceptually unify the physical and virtual spaces. Then the virtual spaces were no longer seen as "devices" in the actual forum space, but as important spaces in their own right. This stage could then work as a common conceptual

platform where the different actors came closer to each other and to the different parts of the entire architecture. In this case, the stage was an idea rather than a physical or virtual space. This idea was then represented in the realised science centre.

Papers IV – VI, together with cases 6-7, focus on exploring RQ2 using the stage metaphor applied in the method of staging. *The Virtual Culture House* and *The Interactive Science Center* illustrate how this method can be used successfully for supporting conceptualisation and implementation of the relations between physical and virtual space. These cases and papers support my argument that stage design is a valid approach and method for designing physical-virtual places.

RQ3: How a Common Place for Physical and Virtual Spaces Can Be Formed

In many everyday situations, as the ones I exemplify in the cases and papers of this thesis, we are interacting in a physical-virtual space. In these situations, we make different agreements with the physical and the virtual spaces, since they are ruled by different and sometimes contradictory metaphors. This creates confusion for the actor/user and prevents the situation from working well as a seeing place. From a design perspective, this forms a design problem, hence a situation where the designer wants to change the world from a current state to a preferred state. The use of the stage metaphor is a proposed solution to this problem.

The concept of a unifying physical-virtual stage formed by physical and virtual objects and spaces, with users as actors on this stage, is a model that depends on agreements between objects, spaces and actors. This means that even though users of physical-virtual spaces still have no control of the original production or setting of the space, they are important actors and part of the on-going negotiation and formation of agreements that the space is constituted by. A physical-virtual space is not fixed but ever changing as it is open to interaction. If we make use of Derrida's post-modern notion of traces in the production of language, we can also talk about traces in the production of space. Following this idea, it is the actors' interaction that actually produces the space. The formation of physical-virtual spaces therefore depends on a holistic view on the physical and the virtual taking form in one gestalt.

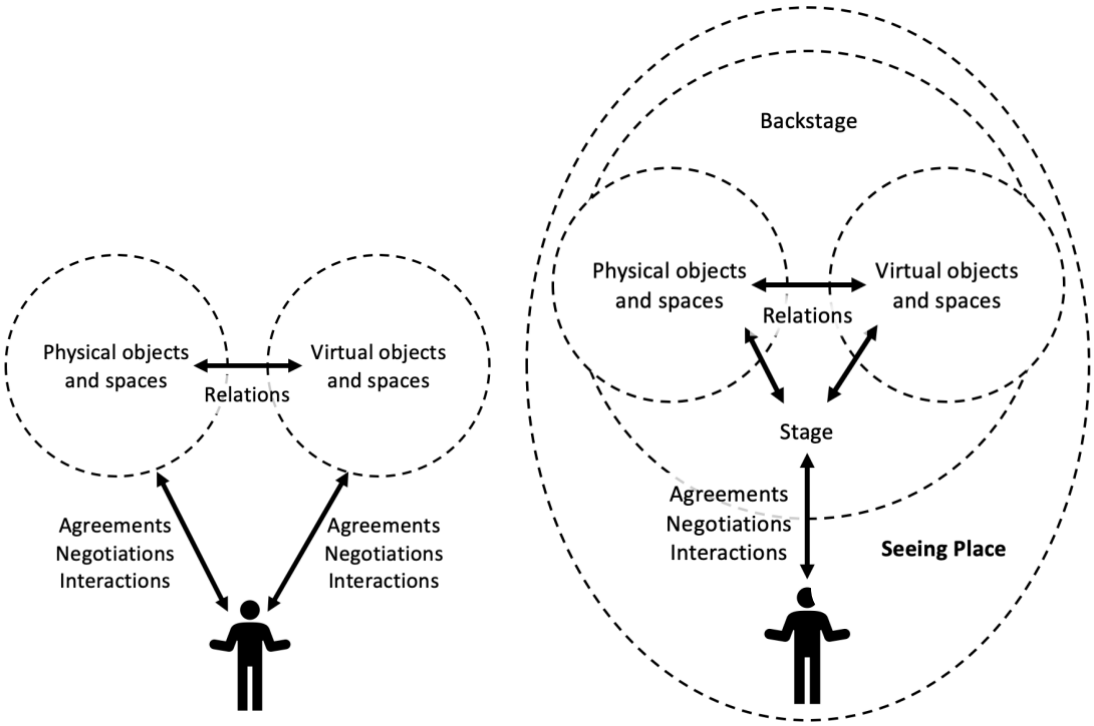


Figure 86. Actors interacting with physical vs. virtual objects and spaces (Wideström, 2020). Left: as described in Fig. 5 of the introduction chapter. Right: A Seeing Place.

To conceptualise this, I propose *A Seeing Place* as a model that includes physical space, virtual space, the actor and the stage metaphor in one gestalt (Fig 86). Figure 86 (right) shows an actor (or multiple actors) interacting with physical and virtual objects and spaces through a unifying stage. This figure is an abstraction of the spatial relations, so that there is no above / below, in front of / behind etc. In this model the actor makes agreements with the stage that includes the physical and virtual spaces. These agreements are negotiated in the interactions between actor and stage. On stage, understood on the higher levels of abstraction, different physical and virtual spaces with different characteristics can co-exist and form the structure and spatial relations. As an extension of my model of a seeing place, we can envision a model with multiple actors and spaces interconnected in a network of actors and spaces.

On the lower levels of abstraction, RQ3 has been explored in the cases of this thesis. They showcase physical and virtual spaces in different contexts, and present how design problems appear and can be addressed, especially in the later cases 3-7. A common aspect of the specific design problems is that there seems to be no unifying concept that works well for both the virtual and the physical parts of the diverse design contexts. In these cases, the model of a seeing place can contribute to creating a more coherent context for the design.

The contribution of *A Seeing Place* is relevant for both designers and design researchers involved in the development and exploration of physical and virtual spaces. For designers, a seeing place provides a design context for complex physical-virtual design problems. Theoretically, the model facilitates the conceptualisation of connecting physical and virtual space. It is based on established theory in philosophy, semiotics, hermeneutics, linguistics, cognition, and aesthetics. *A Seeing Place* model is a result of transdisciplinary research, also congenially connecting these domains on a common stage.

Reflecting on the Transdisciplinarity of the Thesis

Investigation of my research questions has been done through a philosophy of nature. This thesis presents transdisciplinary research, combining insights from interaction design, architecture, natural science, semiotics, phenomenology, philosophy and art. My ambition is not only to make relevant contributions to the domain of virtual reality, but also to propose virtual reality as a suitable space for more transdisciplinary research efforts.

The thesis shows that one of the application domains can be found in the current renaissance of natural philosophy, where we need to interconnect the best theoretical knowledge and best practices from different knowledge domains. Contemporary phenomena, such as virtual spaces, create stages where computer science and technology can meet sciences, humanities and arts. The concepts of virtual space relate to a wide range of research disciplines including natural sciences, philosophy, psychology, cognitive science, social science, and fine arts. The relations between virtual space and these disciplines go two ways: a) virtual space can support transdisciplinary research in representations, simulations, and virtualisations of different combinations of these disciplines, and b) all of these disciplines inform the understanding of virtual space.

For natural science, a deeper understanding of images and virtual spaces as an interface to the world is vital. With the development of new technologies as well as new scientific methods including simulations and advanced visualisations, the connection between the scientist and the world has become increasingly complex. Information in our knowledge about the world is not directly perceived but is mediated through interfaces that transform original data observed “in the world”. This transformation is dependent on the semantics of virtual space and its semiotics.

Solution of practical problems of connecting existing data and knowledge and making them open and accessible to researchers, philosophers, artists and other interested parts is essential for the envisioned natural philosophy as a knowledge approach that builds on all our

existing knowledge that at the same time will enable the study of its goals and values. This project requires a broad natural language as well as visual representations augmented with various other modalities – audio, motion, haptic etc. in new kind of information-rich virtual spaces capable of representing transdisciplinary views of studied phenomena as well as comparative studies.

With the emergence of a variety of virtual environments and hybrid physical-virtual spaces in our everyday life, a deeper understanding of virtuality is needed. This calls for natural philosophy approach on virtual space, in the line of Maxwell's ideas. This perspective is important for the understanding of virtual space, since it embraces both natural sciences, philosophy, and art.

However, a reader might be sceptical of the arguments advancing virtual space as a tool for natural philosophy. Just because a number of concepts that are central for virtual space are also relevant for a number of different scientific domains, it is not necessary that virtual space facilitates the process of recreating natural philosophy. This is why I propose the 'stage' metaphor for the construction of natural philosophy. I highlight the potentials of the emerging area of virtual space to become a platform for cross-disciplinary research. As a stage for multidisciplinarity, virtual space can facilitate the process of recreating natural philosophy as a synthesis of sciences, and philosophy with humanities and arts. It is done so by its richness in aspects, connecting the inherent concepts of virtual space with a wide range of knowledge and practice domains. Here the contemporary phenomenon of virtual space provides a platform for conceptualizing natural philosophy through multidisciplinarity.

An aesthetic perspective on virtual space is also important, since exo-aesthetics (outside aesthetics) shows the relations between actors and objects and the specific conditions of virtual space. From the endo-aesthetic (inside aesthetics) perspective these virtual spaces exist as such only through the interactions between actors and the system. Meaning in this space is not only created in a pipeline from intention to representation to receiver, but also through metaphors and in an interplay between agreements and experiences. The discussion has revealed a synthetic view, where virtual space is seen as a framework for experiences and agreements.

On the other hand, understanding virtual space requires a holistic philosophical perspective, with insights where physical nature, digital information, corporal embodiment, first-person experience, and social aspects come together. Holistic and transdisciplinary approaches like Brier's cybersemiotics provide important framework for understanding virtual space. It becomes clear how meaning in virtual space is created in a semiosis of nature, embodiment, language and subjective experience. The discussion shows how these different perspectives come together in a holistic understanding of virtual space. In this synthetic view, virtual space is seen as a framework for making experiences and agreements. The human is put in the center of virtual space, and therefore in the center of the understanding of natural science and philosophy in this context.

Virtual space as a hybrid combines aspects that would traditionally be considered to belong to the natural or social realms. For Latour, the distinctive characteristic of modern societies is that they differentiate between nature and society, whereas premodern ones did not make this difference. I agree with Latour's opposition of this duality when he argues that our culture needs to reconnect the natural and social aspects. The hybrid of 'virtual space' successfully accomplishes this synthesis. The notion of 'image space' is related to human knowledge fields such as art, art history, visual culture, while 'digital space' relates to technical and natural sciences such as computer science, computer graphics, systems science and simulations. This virtual space hybrid bridging traditionally separate fields facilitates transdisciplinary research in interaction design and cognitive science.

This discussion of virtual space in relation to natural philosophy shows how virtual space can connect different research disciplines. Also, chapter 3 of this thesis elaborates the notion of virtual space offering the suggestion that virtual space can be understood as the

intersection of 'image space' and 'digital space'. This view has the potential to give new insights in virtuality, as a contemporary example of a Latourian hybrid. Moreover, the model of physical-virtual space shows how the physical-digital divide can be resolved for spaces. Building on the foundational debate of the notion of virtuality, the contribution is twofold; firstly presenting how virtual space creates a stage for transdisciplinary collaborations crossing the boundaries of sciences, philosophy, humanities, and arts, and secondly in the way natural philosophy informs the understanding of virtuality.

Discussion

Defining 'virtual' versus 'physical', 'digital', and 'real' in all aspects is complex. The way I frame these concepts is not universal. We might see Virtual Reality as a subset of reality and then just leave it at that. Or use the concept of virtuality to prove that all illusions are virtual. Or even stipulate that real equals physical and virtual equals digital. So why use a term like virtual that is so open to interpretation and negotiation? Well, just because it is. I see the use of virtual as a conceptual metaphor in itself that has the power to redescribe reality. Looking at this concept from different perspectives and frameworks not only explains what virtual means but also creates new meaning in these intersecting or surrounding domains of ideas. This thesis highlights virtual space is a true hybrid of art and science as Latour describes.

Presenting guidelines for how to design physical-virtual spaces has never been the aim of this thesis. Its overall purpose is to raise meaningful questions and propose constructive ideas in the exploration of virtual space through the seeing of the included domains; architecture, interaction design, and theatre. So, this thesis has two target group of readers. It addresses both theoretical and practical issues regarding virtual spaces, making them relevant for designers as well as design researchers.

The level of my own involvement is different in the cases, showing the diversity of research by design as a method. In Case 3, *Baltic Sea Forum*, I contributed with a concept that really changed the way that the people involved understood and experienced the project. In Case 4, *Museum of Natural History*, and Case 5, *Emergency Response Center*, my role was more distant. In Case 6, *Virtual Culture House*, there was no initial setting to develop but rather a set of ideas and visions about a future culture house. This case has the most design contribution from others than me, with a whole range of prototypes that informed and inspired the design process of the project. It is different from the others, with the stage not being set in a specific environment. Altogether, the cases are in different professional domains, with different conditions and levels. However, they present a broad spectrum of situations where the questions of this thesis have been explored.

Also, increased use of virtual spaces raises questions about ethics and sustainability of this new technology. As studies show that the level of interface technology affects performance and collaboration, inequalities in financial resources will transfer into inequalities also in virtual spaces. Moreover, rapid development of VR equipment stimulates buying new devices constantly which produces waste of electronic equipment. Also, all types of impairment (sensory, motor, cognitive, etc.) might not be adapted for in the development of new interfaces. On the other hand, there are already examples showing that some types of impairments could be compensated for by taking advantage of the accessibility of Virtual Reality. Another potential for an increased use of virtual spaces is by replacing actual travelling, for conferences, meetings and alike, with virtual meetings in environments of a high degree of media richness, leading to a positive effect on environmental sustainability.

Conclusion and Future Work

This thesis has brought up the dynamical relationship of physical versus virtual space. The introduction of more and more virtual spaces in our physical architectural spaces has made these relations topical. We experience these virtual spaces using our language and former knowledge of the physical world, but as virtual spaces become used more frequently and over longer time and also richer in media, we also experience physical spaces using our language and knowledge of the virtual world.

There are differences between virtual and physical spaces, in the expectations, agreements, and experiences of the spaces. Connections between the physical and the virtual are made in the way of interdependence, through human interaction. It is the actor, making the agreements with the spaces, that creates the connections and form the relations. While physical and virtual spaces have different properties – in terms of gravity, scale, materiality, tangibility, flexibility, and interaction – there are traces from one space to the other in the chain that connects the actuality of the physical with the potentiality of the virtual. Regarding order of this interdependence, the relation is reflexive, virtual space can work both as interface to physical space as well as vice versa. We cannot see virtual space only as a digital version of physical space. Interacting in a physical-virtual world, meaning is transferred in both directions and the reference for understanding is mutually interdependent.

For designers of contemporary physical-virtual spaces, the cases and results of this thesis can work as a source of insights and inspiration for how to approach complex design problems involving co-existing physical and virtual spaces. The main message for the designer is to see the design problem of space in this context as one, and not solving one design problem for physical space and another for virtual space. Here, the stage metaphor can help the designer to frame the design problem and process. Designers will be able to use a seeing place as model for creating contemporary physical-virtual spaces.

Stage is a strong conceptual metaphor that has many layers and dimensions that fit into both physical and virtual space, linking the two together. As conceptual metaphor, stage leads to other subordinate metaphors, such as scene, actor, audience, drama, décor, props, etc, that can be used by the designer and help the user interacting in these complex situations.

In conclusion, the *Stage* metaphor can form *A Seeing Place*, contributing to the relations between physical and virtual space in many ways, both theoretically and practically. Using stage as metaphor emphasizes agreement, attention and experience as central concepts. Conceptually, it links together the semiotic and the hermeneutic views on space and place. From a practice-based perspective, the stage metaphor can support the connections between physical and virtual, open up the way we create contemporary spaces, and help resolving the physical-virtual divide.

For future work, the stage metaphor and the model of a seeing place will be tested with more cases and contexts. One of the coming projects will be related to Universeum Science Center, where five so called 'visualization labs' will be developed with the focus on letting the visitors interact with real scientific data through a variety of media and interfaces in physical-virtual spaces. This project is connected to a larger project of VR and visualization, aiming at developing new concepts for large-scale immersive projection technologies.

The potential of the virtual seems endless.

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Fig. 12. Virtual concretism. Courtesy of Hans Andersson and Erland Flygt.
Fig. 13. Kinesphere (von Laban, 1948). From book: The Master of Movement, Billing & Sons Ltd, Worcester, 1988. Courtesy of the publisher.
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Fig. 18. Institutiones Geometricae (Dürer, 1532). Source: https://it.wikipedia.org/wiki/Albrecht_Dürer. Accessed 2020-02-02.
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Fig. 25. The Holy Trinity (Masaccio, 1427). Source: https://sv.m.wikipedia.org/wiki/Fil:Masaccio_003.jpg. Accessed 2020-02-02.
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Fig. 28. ”Picnic under the Golden Tree”, front cover of Actor-Spectator in a Virtual Reality Arts Play (Ljungar-Chapelon, 2008), Photo: Sandra Andersson. Courtesy of the author.
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Fig. 62-63. Museum of Natural History in Göteborg. Photos: courtesy of the museum.
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7. Papers

I. The Collaborative Cube Puzzle: A Comparison of Virtual and Real Environments
II. The Pelvis as Physical Centre in Virtual Environments
III. Immersiveness and Symmetry in Copresent Scenarios
IV. Staging the Interaction – Explorative Interventions for Engaging Citizens in the Development of Public Knowledge Institutions
V. The Virtual Culture House – Shaping the Identity of a Public Knowledge Institution
VI. The Transdisciplinary Nature of Virtual Space
VII. Designing For Science Centers - A Classification Framework For The Interaction